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LIQUID HYDROGEN AND HELIUM.*

BY JAMES DEWAR.

Hydrogen is an element of especial interest, because the study of its properties and chemical relations led great chemists like Faraday, Dumas, Daniell, Graham and Andrews to entertain the view that if it could ever be brought into the state of liquid or solid it would reveal metallic characters. Looking to the special chemical relations of the combined hydrogen in water, alkaline oxides, acids and salts, together with the behavior of these substances on electrolysis, we are forced to conclude that hydrogen behaves as the analogue of a metal. After the beautiful discovery of Graham that palladium can absorb some hundreds of times its own volume of hydrogen, and still retain its luster and general metallic character, the impression that hydrogen was probably a member of the metallic group became very general. The only chemist who adopted another view was my distinguished predecessor, Professor Odling. In his "Manual of Chemistry," published in 1861, he pointed out that hydrogen has chlorous as well as basic relations, and that they are as decided, important, and frequent as its other relations. From such considerations he arrived at the conclusion that hydrogen is essentially a neutral or intermediate body, and therefore we should not expect to find liquid or solid hydrogen possess the appearance of a metal. This extraordinary prevision, so characteristic of Odling, was proved to be coriect some thirty-seven years after it was made. Another curious

*** Part of the address of the president of the British Association for the Advancemen of Science delivered at Belfast, Ireland, in September, 1902.**

anticipation was made by Dumas in a letter addressed to Pictet, in which he says that the metal most analogous to hydrogen is magnesium, and that probably both elements have the same atomic volume, so that the density of hydrogen, for this reason, would be about the value elicited by subsequent experiments. Later on, in 1872, when Newlands began to arrange the elements in periodic groups, he regarded hydrogen as the lowest member of the chlorine family; but Mendeleef in his later classification, placed hydrogen in the group of the alkaline metals; on the other hand, Dr. Johnstone Stoney classes hydrogen with the alkaline earth metals and magnesium. From this speculative divergency it is clear no definite conclusion could be reached regarding the physical properties of liquid or solid hydrogen, and the only way to arrive at the truth was to prosecute low-temperature research until success attended the efforts to produce its liquefaction. This result I definitely obtained in 1898. The case of liquid hydrogen is, in fact, an excellent ilustration of the truth already referred to, that no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment. Liquid hydrogen is a colorless transparent body of extraordinary intrinsic interest. It has a clearly defined surface, is easily seen, drops well, in spite of the fact that its surface tension is only the thirty-fifth part of that of water, or about one-fifth that of liquid air, and can be poured easily from vessel to vessel. The liquid does not conduct electricity, and, if anything, is slightly diamagnetic. Compared with an equal volume of liquid air, it requires only one-fifth the quantity of heat for vaporization; on the other hand, its specific heat is ten times that of liquid air or five times that of water. The coefficient of expansion of the fluid is remarkable, being about ten times that of gas; it is by far the lightest liquid known to exist, its density being only one-fourteenth that of water; the lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood. It is by far the coldest liquid known. At ordinary atmospheric pressure it boils at *minus* 252.5 degrees or 20.5 degrees absolute. The critical point of the liquid is about 29 degrees absolute, and the critical pressure not more than fifteen atmospheres. The vapor of

the hydrogen arising from the liquid has nearly the density of air—that is, it is fourteen times that of the gas at the ordinary temperature. Reduction of the pressure by an air-pump brings down the temperature to *minus* 258 degrees, when the liquid becomes a solid resembling frozen foam, and this by further exhaustion is cooled to *minus* 260 degrees, or 13 degrees absolute, which is the lowest steady temperature that has been reached. The solid may also be got in the form of a clear transparent ice, melting at about 15 degrees absolute, under a pressure of 55 mm., possessing the unique density of one-eleventh that of water. Such cold involves the solidification of every gaseous substance but one that is at present definitely known to the chemist, and so liquid hydrogen introduces the investigator to a world of solid bodies. The contrast between this refrigerating substance and liquid air is most remarkable. On the removal of the loose plug of cotton-wool used to cover the mouth of the vacuum vessel in which it is stored, the action is followed by a miniature snowstorm of solid air, formed by the freezing of the atmosphere at the point where it comes into contact with the cold vapor rising from the liquid. This solid air falls into the vessel and accumulates as a white snow at the bottom of the liquid hydrogen. When the outside of an ordinary test-tube is cooled by immersion in the liquid, it is soon observed to fill up with solid air, and if the tube be now lifted out a double effect is visible, for liquid air is produced both in the inside and on the outside of the tube—in the one case by the melting of the solid, and in the other by condensation from the atmosphere. A tuft of cotton-wool soaked in the liquid and then held near the pole of a strong magnet is attracted, and it might be inferred therefrom that liquid hydrogen is a magnetic body. This, however, is not the case; the attraction is due neither to the cotton-wool nor to the hydrogen—which indeed evaporates almost as soon as the tuft is taken out of the liquid—but to the oxygen of the air, which is well known to be a magnetic body, frozen in the wool by the extreme cold.

The strong condensing powers of liquid hydrogen afford a simple means of producing vacua of very high tenuity. When one end of a sealed tube containing ordinary air is placed for a short time in the liquid, the contained air accumulates as a

solid at the bottom, while the higher part is almost entirely deprived of particles of gas. So perfect is the vacuum thus formed that the electric discharge can be made to pass only with the greatest difficulty. Another important application of liquid air, liquid hydrogen, etc., is as analytic agents. Thus, if a gaseous mixture be cooled by means of liquid oxygen, only those constituents will be left in the gaseous state which are less condensable than oxygen. Similarly, if this gaseous residue be in its turn cooled in liquid hydrogen a still further separation will be effected, everything that is less volatile than hydrogen being condensed to a liquid or solid. By proceeding in this fashion it has been found possible to isolate helium from a mixture in which it is present to the extent of only one part in one thousand. By the evaporation of solid hydrogen under the air-pump we can reach within 13 or 14 degrees of the zero, but there or thereabouts our progress is barred. This gap of 13 degrees might seem at first sight insignificant in comparison with the hundreds that have already been conquered. But to win one degree low down the scale is quite a different matter from doing so at higher temperatures; in fact, to annihilate these few remaining degrees would be a far greater achievement than any so far accomplished in low-temperature research. For the difficulty is twofold, having to do partly with process and partly with material. The application of the methods used in the liquefaction of gases becomes continually harder and more troublesome as the working temperature is reduced; thus, to pass from liquid air to liquid hydrogen—a difference of 60 degrees—is, from a thermodynamic point of view, as difficult as to bridge the gap of 150 degrees that separates liquid chlorine and liquid air. By the use of a new liquid gas exceeding hydrogen in volatility to the same extent as hydrogen does nitrogen, the investigator might get to within five degrees of the zero; but even a second hypothetical substance, again exceeding the first one in volatility to an equal extent, would not suffice to bring him quite to the point of his ambition. That the zero will ever be reached by man is extremely improbable. A thermometer introduced into regions outside the uttermost confines of the earth's atmosphere might approach the absolute zero, provided that its parts were highly transparent to all kinds of radiation, otherwise it would be affected by the

radiation of the sun, and would therefore become heated. But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero, it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in the properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction in those which are as yet unexplored. Of such a breakdown low-temperature research has already yielded a direct proof at least in one case. A series of experiments with pure metals showed that their electric resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air and less powerful refrigerants. But with the advent of the more powerful refrigerant liquid hydrogen it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly by being placed in the exhausted receiver of an air-pump, undergo a reduction in temperature, but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no such reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion as theory indicated. Hence it was the platinum thermometer which had broken down; in other words, the electrical

resistance of the metal employed in its construction was not, at temperatures about *minus* 250° C., decreased by cold in the same proportion as at temperatures about *minus* 200°. This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the silimarity between the behavior of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also. At any rate, the knowledge that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of that property with temperature is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature. Lord Kelvin evidently anticipates the possibility of more remarkable electrical properties being met with in the metals near the zero. A theoretical investigation on the relation of "electrions" and atoms has led him to suggest a hypothetical metal having the following remarkable properties; below one degree absolute it is a perfect insulator of electricity, at two degrees it shows noticeable conductivity, and at six degrees it possesses high conductivity. It may be safely predicted that liquid hydrogen will be the means by which many obscure problems of physics and chemistry will ultimately be solved, so that the liquefaction of the last of the old permanent gases is as pregnant now with future consequences of great scientific moment as was the liquefaction of chlorine in the early years of the last century.

The next step towards the absolute zero is to find another gas more volatile than hydrogen, and that we possess in the gas occurring in clevite, identified by Ramsay as helium, a gas which is widely distributed, like hydrogen, in the sun, stars and nebulæ. A specimen of this gas was subjected by Olszewski to liquid air temperatures, combined with compression and subsequent expansion, following the Cailletet method, and resulted in his being unable to discover any appearance of liquefaction, even in the form of mist. His experiments led him to infer that the boiling-point of the substance is probably below nine degrees absolute. After Lord Rayleigh had found a new source of helium in the

gases which are derived from the Bath springs, and liquid hydrogen became available as a cooling agent, a specimen of helium cooled in liquid hydrogen showed the formation of fluid, but this turned out to be owing to the presence of an unknown admixture of other gases. As a matter of fact, a year before the date of this experiment, I had recorded indications of the presence of unknown gases in the spectrum of helium derived from this source. When subsequently such condensable constituents were removed, the purified helium showed no signs of liquefaction, even when compressed to eighty atmospheres, while the tube containing it was surrounded with solid hydrogen. Further, on suddenly expanding, no instantaneous mist appeared. Thus helium was definitely proved to be a much more volatile substance than hydrogen in either the liquid or solid condition. The inference to be drawn from the adiabatic expansion effected under the circumstances is that helium must have touched a temperature of from nine to ten degrees for a short time without showing any signs of liquefaction, and consequently that the critical point must be still lower. This would force us to anticipate that the boiling-point of the liquid will be about five degrees absolute, or liquid helium will be four times more volatile than liquid hydrogen, just as liquid hydrogen is four times more volatile than liquid air. Although the liquefaction of the gas is a problem for the future, this does not prevent us from safely anticipating some of the properties of the fluid body. It would be twice as dense as liquid hydrogen, with a critical pressure of only four or five atmospheres. The liquid would possess a very feeble surface-tension, and its compressibility and expansibility would be about four times that of liquid hydrogen, while the heat required to vaporize the molecule would be about one-fourth that of liquid hydrogen. Heating the liquid one degree above its boiling-point would raise the pressure by one and three-fourth atmospheres, which is more than four times the increment for liquid hydrogen. The liquid would be only seventeen times denser than its vapor, whereas liquid hydrogen is sixty-five times denser than the gas it gives off. Only some three or four degrees would separate the critical temperature from the boiling-point and the melting-point, whereas in liquid hydrogen the separation is respectively ten and

fifteen degrees. As the liquid refractivities for oxygen, nitrogen, and hydrogen are closely proportional to the gaseous values, and as Lord Rayleigh has shown that helium has only one-fourth the refractivity of hydrogen, although it is twice as dense, we must infer that the refractivity of liquid helium would also be about one-fourth that of liquid hydrogen. Now hydrogen has the smallest refractivity of any known liquid, and yet liquid helium will have only about one-fourth of this value—comparable, in fact, with liquid hydrogen just below its critical point. This means that the liquid will be quite exceptional in its optical properties and very difficult to see. This may be the explanation of why no mist has been seen on its adiabatic expansion from the lowest temperatures. Taking all these remarkable properties of the liquid into consideration, one is afraid to predict that we are at present able to cope with the difficulties involved in its production and collection. Provided the critical point is, however, not below eight degrees absolute, then from the knowledge of these conditions that are successful in producing a change of state in hydrogen through the use of liquid air, we may safely predict that helium can be liquefied by following similar methods. If, however, the critical point is as low as six degrees absolute, then it would be almost hopeless to anticipate success by adopting the process that works so well with hydrogen. The present anticipation is that the gas will succumb after being subjected to this process, only, instead of liquid air under exhaustion being used as the primary cooling agent, liquid hydrogen evaporating under similar circumstances must be employed. In this case the resulting liquid would require to be collected in a vacuum vessel, the outer walls of which are immersed in liquid hydrogen. The practical difficulties and the cost of the operation will be very great; but on the other hand, the descent to a temperature within five degrees of the zero would open out new vistas of scientific inquiry, which would add immensely to our knowledge of the properties of matter. To command in our laboratories a temperature which would be equivalent to that which a comet might reach at an infinite distance from the sun would indeed be a great triumph for science. If the present Royal Institution attack on helium should fail, then we must ultimately succeed by adopting a process based on the mechanical

production of cold through the performance of external work. When a turbine can be worked by compressed helium, the whole of the mechanism and circuits being kept surrounded by liquid hydrogen, then we need hardly doubt that the liquefaction will be effected In all probability gases other than helium will be discovered of greater volatility than hydrogen. It was at the British Association Meeting in 1896 that I made the first suggestion of the probable existence of an unknown element which would be found to fill up the gap between argon and helium, and this anticipation was soon taken up by others and ultimately confirmed. Later, in the Bakerian Lecture for 1901, I was led to infer that another member of the helium group might exist having the atomic weight about 2, and this would give us a gas still more volatile, with which the absolute zero might be still more nearly approached. It is to be hoped that some such element or elements may yet be isolated and identified as coronium or nebulium. If amongst the unknown gases possessing a very low critical point some have a high critical pressure, instead of a low one, which ordinary experience would lead us to anticipate, then such difficultly liquefiable gases would produce fluids having different physical properties from any of those with which we are acquainted. Again, gases may exist having smaller atomic weights and densities than hydrogen, yet all such gases must, according to our present views of the gaseous state, be capable of liquefaction before the zero of temperature is reached. The chemists of the future will find ample scope for investigation within the apparently limited range of temperature which separates solid hydrogen from the zero. Indeed, great as is the sentimental interest attached to the liquefaction of these refractory gases, the importance of the achievement lies rather in the fact that it opens out new fields of research and enormously widens the horizon of physical science, enabling the natural philosopher to study the properties and behavior of matter under entirely novel conditions. This department of inquiry is as yet only in its infancy, but speedy and extensive developments may be looked for, since within recent years several special cryogenic laboratories have been established for the prosecution of such researches, and a liquid-air plant is becoming a common adjunct to the equipment of the ordinary laboratory.

PLANT PHYSIOLOGY IN THE HIGH SCHOOL.

BY C. R. BARNES.

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Ever since the natural sciences began to make their way into the curriculum of secondary schools, discussion as to the character and amount of instruction to be offered in each has formed an important topic in educational meetings and journals. Oftentimes these discussions have shown a strong bias on the part of the advocate of some particular subject, a bias due either to temperament or to special training, or to the nature of the work in which he is engaged. It is difficult for any one to eliminate such bias. It becomes increasingly difficult for one to do so as the field in which his immediate interest lies becomes more and more limited. Therefore the college teacher has oftenest evinced in such discussions a bias leading even to dogmatism. On this account, indeed, teachers in our secondary schools are tempted to discount or to reject without fair consideration the suggestions and advice of university men. I hope, however, that a short personal experience in a city high school, and a somewhat prolonged and intimate acquaintance with high schools of various grades of equipment and the usual limitations as to time, may enable me to write in moderation upon this topic, even though at present it forms the sole subject of my teaching.

It has been conceded generally that botany should have a place in the high-school curriculum, if not as a required subject, at least as an elective with zoölogy. The ease with which material may be secured and preserved, the absence of any repugnance to its handling, and the importance of plant activities in the world's work amply justify its inclusion. For a long time, however, botany was supposed to have as its most important function the acquainting of the pupils with the different kinds of flowers or trees which grew in a limited region. The whole training, therefore, was directed to such a knowledge of anatomy, and particularly of the technical descriptive terms, as would be useful to this end. In all the better schools, however, this limitation of study to the plants of a single group, with a somewhat trivial end in view, has

given way to a more comprehensive study of all the great divisions of plants, to gain the broader and truer conception of the plant kingdom as a whole. In doing this, laboratory work was at first overdone. Latterly, in the wise attempt to regain some features of the valuable training of outdoor naturalists, attention has been given to the relations of plants to the situations in which they grow and to one another, i. e., ecology. For such ecological study a physiological background is most important. But even where ecology has as yet made no way as an elementary subject, the claims of physiology to share with morphology have been pretty generally conceded. The reasons for this are evident enough. What the living being can do is interesting to almost every one, though the trouble necessary to see this is sometimes sufficient to deter the indifferent from the endeavor. But interest becomes awakened when to a knowledge of the structure of plants is added a study of the machinery in action. Physiology, furthermore, gives a kind of training not gained from morphology, and so enriches the whole subject.

If, then, there is a general course in botany, which we may assume to cover at least half a year, and preferably the whole year, what should be the character of that portion of it which is devoted to physiological work? In what relation and proportion should it stand to the other work? What ends should be kept in view?

Before answering these questions I may say by way of introduction that the work should be experimental. No mere study of a book about how plants grow or what they can do will be either interesting or valuable, except to the limited number whose interest in plants is already alive. A book may be necessary (in my judgment it is indispensable) as an accompaniment to the laboratory work, but the experiments themselves should be the main feature and the reading supplementary thereto.

Material for such a course can be grown readily in any greenhouse. Seedlings which can be quickly grown in the laboratory furnish the subjects of many an experiment. A few living plants, which may be derived from window gardens or from commercial greenhouses, will be necessary. One requisite, which in some of the smaller schools is more difficult to secure, is a room that is

not allowed to become cold at nights or on holidays. In such a place, however, if it be impracticable to heat the room from the main furnaces, a baseburner may be provided at small cost, which will obviate the difficulty.

The equipment necessary is also easily obtainable. The few chemicals, tubing, glassware, etc., are already at hand in the chemical or physical laboratory, or can be secured at small cost. In a correspondence course given here, which was more extended than would be suitable for a high school, it was found that the equipment needed for a single student working at home could be supplied for less than \$15. I need hardly say that this would not be multiplied by twenty were a class of twenty working. The apparatus necessary is also limited in amount, and most of it can be constructed by the teacher and pupils at a small cost.[1]

I. In an elementary experimental course in plant physiology the study of the most fundamental functions only can be included. The experiments should illustrate how materials get into and out of the plant, a topic which will include the absorption of water and dissolved salts by the roots, of gases (O_2 and CO_2) by the leaves and transpiration. The conditions under which green plants make food should also be determined. Respiration, one of the most widely misunderstood functions of plants, should not be slighted. And finally, growth and movement, being manifested by obvious changes of form or position and readily modifiable by changing the external conditions, should be used to show the sensitiveness of plants and their responses to stimuli. There are a number of books from which experiments on these subjects can readily be selected. These may be modified to suit the conditions of the laboratory in which they are carried out, and will be both illustrative of important facts in plant life and deeply interesting to many students who otherwise would be indifferent.

II. The work in plant physiology may be presented either in connection with the study of morphology or may follow it as an independent division of botany. In my judgment it makes

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[1]Lists of material and apparatus will be found in the appendix to my *Plant Life*, and admirable suggestions as to material and apparatus for a much more extensive course will be found in Ganong's *Laboratory Course in Plant Physiology*. Both are published by Henry Holt and Company.

little difference which of these two methods is pursued. Both have strong advocates, the former especially being the favorite of those who speak from a theoretical standpoint. It may be pointed out, however, that if one chooses to introduce the study of absorption after a consideration of the structure of the root, and to illustrate transpiration and photosynthesis after the examination of leaves, there can be no serious objection to it, provided certain dangers of omission are guarded against. Too often thus the leaves are left out of consideration as absorbing organs, absorption being associated wholly with the study of the roots. In reality, however, the absorption of gases by the leaves is of quite as much importance as any absorption by roots.

As to the amount of time to be devoted to physiology, it may fairly claim at least one-third, supposing that morphology and ecology share with it; and such a claim would certainly not be unfair if morphology alone were its companion. But no rigid relation of time is necessary or desirable.

III. The purpose of such a course in plant physiology should be primarily to stimulate interest in living things, and to cultivate power of observation; a secondary object should be to illustrate right methods of experimentation and inference. In such an elementary course one danger is to be guarded against most strenuously and continually, namely, the danger of permitting students to imagine that a single experiment, not rigidly quantitative, may be the basis of correct inference. They should be repeatedly warned that such experiments as they are making are merely illustrative of the way in which new knowledge can be gained. The fundamental rule of experimentation must be rigidly adhered to; namely, to have only one variable factor in the experiments. Control experiments under conditions identical except one are indispensable. It behooves the teacher of physiology also to be strictly on guard against the inculcation of bad physics. Much of our physiology, both plant and animal, suffers under this reproach today.

The question is often asked whether the experiments in such courses should be made quantitative. I should reduce the quantitative work in botany to a minimum, for the simple reason that training of this kind can be gained most easily and satis-

factorily in handling material less complicated than living plants. I believe firmly in quantitative experiments in elementary physics and chemistry. In the college or university quantitative work may properly be demanded in the extended courses in plant physiology.

Finally, I may touch the question, in what year of the course should such work be given? I refer to it not to discuss it, but to say that in my judgment it is not worth the time and energy which have been expended upon it. It is clear enough that a *logical* order demands physics and chemistry as a foundation for biology, but it is equally clear that other considerations beside logical order enter into the problem. The teacher who has any capacity for adaptation will be able to handle the botany in the first year or in the fourth. Naturally the two will be quite different in character. If physiology, therefore, comes before courses in physics and chemistry it will be necessary for the teacher to introduce such physical and chemical notions as are indispensable to an understanding of the experiments. This will limit his time and the character of his experiments. But they need not seriously interfere with such a course as I have suggested.

THE FEEDING HABITS OF FISHES.

BY C. JUDSON HERRICK,

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There is many a successful teacher of the natural sciences in our high schools who has not had a university training and who may possibly never have had the advantage of advanced work in any department of science, but who is nevertheless keenly alive to the truth of the familiar pedagogical maxim, that to be an inspiring teacher he must keep in touch with the most advanced movements of his subjects. While he cannot sweep the whole field of current research in all of his subjects, he can at least keep abreast of some small specialty and so vitalize his teaching to some degree with the real live blood of scientific progress. If possible he should from time to time contribute something to this specialty himself, some new fact or generalization which may be of value to others.

There are many fields in natural history which are still very accessible to observation and experiment and that, too, with no other equipment than a pair of good eyes and a patient, logical mind, if only one knows where to look for them. For instance, we are profoundly ignorant of the most common-place features of the daily life of most of the more lowly animals. The senses of fishes have been but little studied, and that with most diverse results. One author declares that fishes do not smell at all, another that some kinds find their food in that way alone, while a third affirms that fishes do not taste at all. Now, it will be possible (I do not say it will be easy) for any one who is free from bias and who has sufficient patience, ingenuity and critical ability, to devise simple experiments which will answer definitely some of these questions. The simplicity of some of these problems may be illustrated by the following experiments in my own recent experience.

In the course of a series of papers which have been running through *The Journal of Comparative Neurology* during the past three or four years, I have worked out the structure and nerve supply of the sense organs in a number of kinds of fishes. Taste buds similar in structure and nerve supply to our own are always found abundantly in the mouth of fishes. That they do taste with these organs can be easily shown by experiment. Thus, if a fish is fed with bits of soft meat, he swallows them instantly; but if now bits of gelatine well softened in cold water are substituted for the meat, the pieces may be taken into the mouth, but they are at once rejected. The gelatine may be colored to look like the meat and to the sense of touch it is exactly the same, but the instant it gets into the mouth the discrimination is made.

Now, in some fishes (but not in all) similar sense organs, known as "terminal buds," are found outside the mouth—all over the skin of the body in the cyprinoids, or carp tribe, on the barblet and free rays of the ventral and dorsal fins in the ganoids, or cod tribe, and on the barblets and very abundantly all over the body in the siluroids or cat-fish tribe. In all of these cases I have traced out by a microscopical method the innervation of these cutaneous organs and I have found that, however devious the path by which their nerve fibers pass back to the brain, they always reach a com-

mon center, which is also the center which receives the nerve fibers from the undoubted taste buds in the mouth. This, of course, is strong presumptive evidence that the terminal buds of the outer skin have a gustatory function; but presumptions are not satisfactory in scientific work when facts are obtainable.

To test this hypothesis then, the feeding habits of a lot of young cat fishes were studied. The cat fishes never seem to see a bit of meat thrown into the water nor to find their food by the sense of sight at all, but if a barblet or the body anywhere touches such a piece of meat the fish snaps it up instantly. In swimming they constantly drag the bottom with the barblets for this purpose. If the body is touched anywhere with a bit of meat on a long wire, the meat is taken the same way; but if the fish is touched with a wisp of white or red cotton or other tasteless thing, he may turn and touch it with a barblet once or twice, but after a few such experiences the fish pays no more attention to it. If a jet of meat juice is squirted against the side of the body of the fish under water with a fine pipette, the fish makes the same reaction as he would if touched by a piece of meat; but if a jet of water is used he pays no attention to it. These and many similar experiments indicate that the cat fishes can taste not only in the mouth, but also over the whole body surface and particularly with the barblets, and that this sense is the one chiefly relied upon in finding their food.

This is by no means the case with all fishes, for most of them undoubtedly find their food chiefly by the sense of sight, and, though I have tested in the manner described above a considerable number of species, I do not get these characteristic gustatory responses from the outer skin except from fishes which have the terminal buds in the areas stimulated. I have worked also with the tom cod, hake and other fishes of the cod tribe, with essentially the same results.

Of course in these reactions there is generally both a gustatory and a tactile reaction involved. The parts are supplied with both kinds of nerves and I find in general that where the terminal buds are very abundant, as in the cat fish, the gustatory element is more important, while in the tom cod, where the terminal buds are present in less numbers, the tactile element plays a much

larger part in the reflex of seizing food. It may properly be asked whether the sense of smell plays any part in these reactions, and to test this I destroyed the olfactory nerves of both sides in a tom cod by cutting them off. After recovery from the operation he was placed in the same tank with normal specimens and I could observe no difference in their behavior, and hence conclude that these responses were independent of any function associated with the nose of the fish.

The reader will observe that these experiments involve the use of practically no apparatus. They are not, however, so simple as may appear on the surface, since to be of value every observation must be controlled by repetitions from as many points of view as possible, and no small amount of patience is required to get the animals to feel at ease and react to experimental conditions in a perfectly normal way. It is, nevertheless, intensely interesting work and well repays the observer for any expenditure of time and effort. My own experiments will be reported upon at length in the forthcoming volume of the *Bulletin of the U. S. Fish Commission,* to which the reader is referred for further details. There are scores of similar problems connected with the life of the fishes alone, to say nothing of the other lower animals, and real facts, acquired at first hand, thoroughly controlled and digested, are the foundations of all sciences.

MATTER AND METHOD IN PHYSICS TEACHING.*

BY R. H. CORNISH.

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I shall not, at this late day, make any special plea for the sciences in general or for physics in particular. These studies find a place more or less conspicuous in the program of every high-school in the country. The endowed academies and private schools all make provision for science teaching. The latest catalogue of Phillips Andover Academy, the oldest endowed academy

*Abstract of an address delivered April 18, 1902, before the Department of Pedagogy, Cornell University.

in New England, and for more than a hundred and twenty years a great classical preparatory school, places physical geography as a required study in its first year and physics, chemistry and botany in the fourth year of its classical course. Many colleges permit the substitution of physics or chemistry for Greek or a modern language in their entrance requirements. To say that the sciences are everywhere accepted as equivalent to languages and mathematics as college entrance requirements would be stating more than the truth. No such claim is made. But that they are everywhere recognized as one of the great instruments of culture worthy of serious attention, and consequently to be provided for both by program makers and by those who furnish the material equipment, is to state the simple truth.

The questions now in dispute are not as to the wisdom of including science in the secondary school program nor how can it justify itself practically or pedagogically. Those questions have been answered. The questions now in dispute are such as these: (1) What sciences shall be prescribed and what shall be optional? (2) What methods of instruction shall be followed? (3) In what order shall the different branches of science be taken up? (4) What shall be attempted in a one-year's course of any particular branch? These questions all have many different answers. If you were engaged in arranging a course of study for a school or system of schools, the first and third questions would demand immediate answers, viz.: In what order shall the sciences be taught and what shall be taught?

In endeavoring to answer these questions it is to be noted that science (by which I mean objective knowledge, knowledge that exists outside the mind) is one, and that it is only for our convenience that we divide it up into parcels and label these parcels physics, chemistry, biology, geology, and that these parcels are every year growing larger and larger with astonishing rapidity. Also since all science is one, its different branches are closely related, and mutually dependent. The terms physics, chemistry and all the rest do not denote sharply divided territories like the towns of a county, but regions of knowledge which overlap other regions. Chemistry and physics have a theoretic distinction clear and sharp, but practically they are closely dependent and related.

Every physics teacher must know something of chemistry, while physical chemistry is a most important part of general chemistry. Biology includes many problems of both physics and chemistry, while physical geography is very largely concerned with finding out how physical, chemical, and biological forces are modifying the earth's surface.

Prof. T. C. Chamberlain says that each science depends upon every other science; hence each science should logically precede every other in the course of study. This paradox is only an emphatic way of stating the difficulty of the problem. The moral of all this for the teacher of science is the very obvious one that in order to be successful in one an acquaintance with all is very desirable. The larger his knowledge, the better for the teacher.

This question of what is the proper sequence of science studies is one of the most disputed and most disagreed about that we have to discuss. For example, Prof. Woodhull, of the Teachers' College, New York, argues earnestly for placing chemistry in the first year of the high-school course. He claims that both logical arrangement and the needs and interest of the pupil are favored by this method. The simplicity of the apparatus needed, its ease of manipulation, and inexpensiveness he urges as favorable to his plan. Such a course as he describes would, I am sure, be a valuable one. I should like to see such a course forming a part of a larger course for the first year. I know of very few schools, however, that adopt this plan. The Committee of Ten places physical geography in the first year; physics and botany or zoölogy in the second; astronomy and meteorology in the third, and geology, or physiography, or anatomy, or physiology, in the fourth.

This lack of agreement as to sequence is unfortunate. Any arrangement will find objectors and any arrangement may, with judicious teachers, produce good results. There is no doubt that every science has an elementary and an advanced stage. Physics, for example, taught to first-year pupils, must be presented in a very different way from physics taught to third or fourth-year pupils. The latter have the requisite mathematical knowledge and maturity of mind to profit by an advanced method of presentation. They have also, presumably, studied for one or two years some other branch of science. This has had its effect in widening the

mental horizon. The same is true of other branches. Any first-year science would necessarily be narrower than the same science would be if presented in the last year. In order to meet this desire to have some facts in hand when the student begins the serious study of any particular branch of science it has always seemed to me that a course of physiography, in the English sense of the word, would be a most desirable plan. This means a systematic course in elementary science of all kinds, elementary physics, chemistry, geology, botany, astronomy. Such a course should be followed by a serious and detailed study of at least one branch of science in each of the succeeding years of the course. If nature study has been systematically presented during the pupils' primary and grammar school course, especially during the 7th, 8th and 9th grades, then such an introduction as I have described would not be necessary, and the pupil might at once take up some branch of science in a more detailed and thorough manner. In the new program of study for the high-schools of the Boroughs of Manhattan and Bronx the arrangement for the sciences is as follows: First year, biology, required in all courses, 4 hours per week. Second year, physiography or chemistry in the scientific course; third year, physics, required in all courses, 5 hours per week. Fourth year, biology, chemistry, astronomy and physiography, elective, each, 4 hours per week.

The course of study for a large city, like New York, is a very important matter. It will affect very soon not less than 10,000 high-school pupils; if extended to all the boroughs, probably twice that number. Several things may be noted with reference to the science studies of this course: (1) All the sciences which are included, whether required or elective, occupy one year, 4 or 5 periods per week. Thus is recognized the wisdom of abandoning the half-year, or 14-week, courses in science, which have been so popular in the past. (2) The biological sciences represented by biology and physiology, and the physical sciences, represented by physics, are required of all pupils in all courses. All teachers of science must approve of these two facts. This arrangement gives to two very important subjects proper recognition and value. (3) Physiography, or physical geography, a representative earth science, is required in one course only and even there it competes

with chemistry for recognition. This I believe unfortunate and I wish that this branch had been required in all courses except the classical.

That arrangement, with the recognition of biology and physics which has been made, would have left the science teachers with little to ask, and would have furnished a wise and defensible program upon which all science teachers could unite, for it is to be noted (4thly) that astronomy, advanced biology, chemistry, physiography (and to this list we hope to add advanced physics) are offered as elective studies of the fourth year. This latter point will, I think, meet with general approval.

The whole arrangement, therefore, with the exception I have noted with regard to physiography, disposes in a fairly satisfactory manner of the vexed questions—what sciences shall be taught, what shall be elective and what required? There is not time in this discussion for stating the reasons for making certain subjects required and others elective, but the reasons are hinted at in the use of the phrases, biological sciences, earth sciences, and physical sciences.

For myself, I do not think that the discussion as to the order in which the various sciences shall be taught is very interesting nor very important. The main thing is to have whatever science comes first properly taught; taught so that it shall be stimulating to the observing powers; taught with due regard to the student's stage of progress, and so taught that it shall furnish a real introduction to a scientific method. And with a competent, thoughtful, enthusiastic teacher this will be done.

I have no objections, therefore, to Mr. Woodhull's having chemistry in the first year of the Horace Mann school, nor to Mr. Peabody's having biology in the first year of the high schools of Manhattan and Bronx, nor shall I object to your own Prof. Wilder's introducing the laboratory study of calves' brains into the grammar schools of Ithaca. With his mastery of the subject and his great enthusiasm I have no doubt that that also would be profitable.

The relation of physics to mathematics is more close and dependent than the relation of physics to any inductive science. The laws of physics are statements of the relations existing between two or more variable quantities. The highest aim of the physicist

is to discover the relations existing between the varying quantities which are before him and which change together. Besides this exact and mathematical relation which the physicist aims to discover and state in the briefest and most exact language, the elementary study of physics constantly uses geometric ideas, terms and definitions, and to a smaller extent the processes of elementary algebra. These should be thoroughly embedded in the student's mind, if he is to make the most progress and get the most from the study. The more the pupil knows of arithmetic, algebra and geometry, the easier becomes his mastery of physics. This knowledge of elementary mathematics cannot be too thorough or complete. This use of geometry and geometric ideas is most marked in mechanics and optics. Hardly a step can be taken in the study of light without running against geometric terms and propositions. It has already been said that the laws of physics are statements of the relations existing between two or more variables. These statements use the language of variation for their expression. But variation is only a condensed proportion and proportion is an equality of ratios. Therefore from the standpoint of the physics teacher ratio, proportion and variation are the most important topics which the algebra contains.

If physics is to have its full value in mental development, then the pupil should have all the mathematical training and mental maturity possible. The science of physics has two foundation stones: mathematics and experiment. One is as important as the other. If it is mathematical it is also experimental and inductive. Those generalizations which we call laws are in every case statements of what would be true if the conditions were ideal, and this is never true. On account of this dependence of physics upon mathematics, all teachers of physics urge postponing its formal study as late as possible in the course. The new course of study in New York, to which I have referred, places physics in the third year after plane geometry and elementary algebra have both been studied.

I shall not undertake to define nature study for you, as that has been done by Prof. L. H. Bailey in the twenty-fifth lecture of this course. He says: "The proper objects of nature study are the things one oftenest meets. Today it is a stone, tomorrow

it is a twig, a bird, an insect, a leaf. The child or even the high-school pupil, is first interested in things which do not need to be analyzed or changed into unusual forms or problems. Therefore, problems of chemistry or physics are for the most part unsuited to early lessons in nature study." I suspect he is right and that objects of natural history are in general best to begin with in the informal study of science. Observational lessons on clouds, rain, dew, running water, ice, frost, snow, are perhaps next in simplicity. The informal study of very many of the facts and phenomena of physics and chemistry might next be taken up. This simple, non-mathematical observational method of studying physics is, it seems to me, a part of nature study, and appropriate to grades below the high-school. To understand what takes place when a kettle boils, when a candle burns, when the dew "falls," when the rainbow appears, requires considerable intelligence and thought; more, I think than comparing the forms of leaves or noticing the habits of an animal. Therefore physics and chemistry should come last in the nature study course of the grammar school. But that it should be included in the elementary school course, I firmly believe. Prof. Bailey says: "The only way to teach nature study is with no course laid out, to bring in whatever object may be handy, and to set the pupils looking at it." It seems to me, however, that if any progress is to be made in physics or chemistry as a branch of nature study, there must be much careful planning on the teacher's part. Many helpful books have been written and much thought given to planning this sort of work for grammar schools. For example, in the elementary schools of Montclair, N. J., a course of combined physics and chemistry is a part of the work of the last three years in the 7th, 8th and 9th grades.

Some grammar schools have attempted more than this. The Cambridge (Mass.) Grammar Schools several years ago adopted a course elaborated by Prof. E. H. Hall, of Harvard, and described in his little book called "Lessons in Physics." This course comprehended individual laboratory work by the pupil and much demonstration work by the teacher. It occupied one hour per week throughout a year, and included the performance of twenty-seven individual laboratory exercises.

(Concluded in January.)

A DIAGRAM ILLUSTRATING UNIFORMLY ACCELERATED MOTION.

BY HERMAN D. STEARNS.

Associate Professor of Physics, Leland Stanford University.

Fig. 1 contains three right triangles. The sides *AB, BC* and *BD* are represented arbitrarily by the symbols $\frac{2}{a}$, *S* and *T*. The geometry of the figure shows that

$$S = \tfrac{1}{2}\, a\, T^2 \qquad (1)$$

Let the points *A* and *B* be fixed; $\frac{2}{a}$ is then fixed. Let the point *D* start at *B* and move uniformly in the direction *BD* with

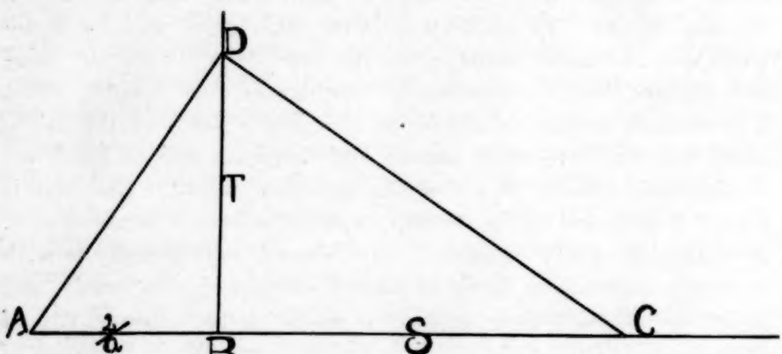

Fig. 1.

unit velocity. *BD,* measured in units of length, is then numerically equal to the time *T* measured in seconds and the purpose of the symbol *T* is plain.

During the motion of *D* let the point *C* move in the direction *ABC* so that the angle *ADC* shall always be a right angle. To fulfill this condition *C* and *D* must leave *B* at the same instant and *T* represents the time required by the point *C* in moving the distance *BC* or *S*.

Equation (1) now expresses the space passed over by the point *C* in terms of the time *T* and a fixed quantity *a* and the equation is seen to be that of uniformly accelerated motion, the rate of acceleration being *a*.

Two simple cases will serve for illustration:

Suppose that *A* is a powerful source of light and that a uni-

formly moving car D carries a mirror that rotates in such a way as to reflect a beam of light from A at right angles to AB and against a wall BC. The spot of light will move along the wall with uniform acceleration.

Suppose, again, that A in Fig. 2 is a knife edge and that a carpenter's square moves so that one arm slides against A while the vertex of the right angle moves uniformly along BD. If the other arm drives a particle C along a grooved track BC, C will move with uniform acceleration.

In both these cases the rate of acceleration will be a if D move

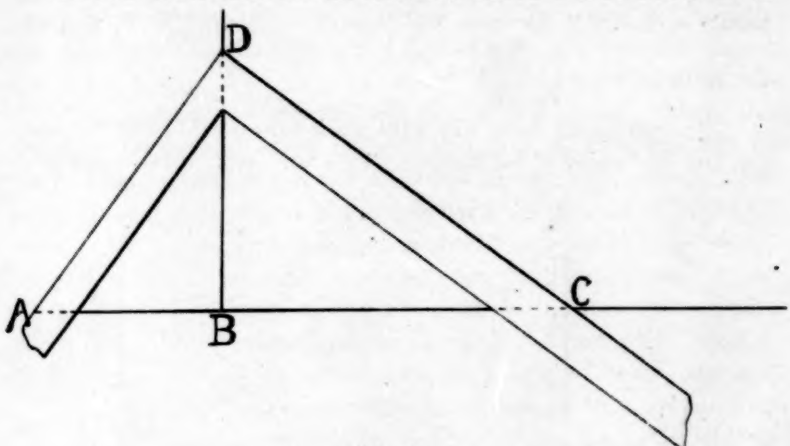

Fig. 2.

with unit velocity. If D move with any other uniform velocity the rate of acceleration will be proportional to a.

If this geometrical method were used in presenting the subject of uniformly accelerated motion to a student for the first time, it would be necessary to show that equation (1) represents such motion. The usual algebraic method is to express the mean velocity $\bar{v}$ during the time $T_2—T_1$ by the equation

$$\bar{v} = \frac{S_2 - S_1}{T_2 - T_1} = \tfrac{1}{2}\, a\, \frac{T_2^2 - T_1^2}{T_2 - T_1} = a\, \frac{T_2 + T_1}{2}$$

Hence,

$$\bar{v} = a\,T, \qquad (2)$$

where T is midway between T_1 and T_2.

Since the same value is obtained for $\bar{v}$ for all values of

the interval $T_2—T_1$ if the mid-point T remain unchanged, it follows that the mean velocity $\bar{v}$ is the actual velocity v at the instant T.

Hence,

$$v = a\,T. \qquad (3)$$

Equation (3) contains the definition of uniform acceleration.

However, equations (2) and (3) may be approximately obtained from the diagram without the use of algebraic methods.

Draw Fig. 3 as accurately as possible and locate a point T midway between two points T_1 and T_2. Locate the corresponding points S_1 and S_2. Measure the lines $S_2—S_1$ and $T_2—T_1$ and find the value of $\bar{v} = \dfrac{S_2—S_1}{T_2—T_1}$

Proceed in the same way with other values of T_1 and T_2, keeping the mid-point T unchanged. This will lead to the determina-

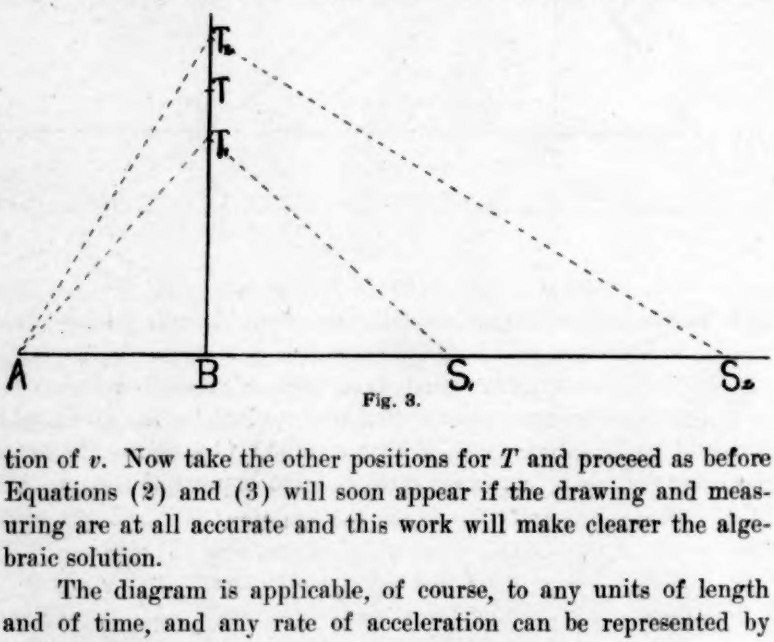

Fig. 3.

tion of v. Now take the other positions for T and proceed as before Equations (2) and (3) will soon appear if the drawing and measuring are at all accurate and this work will make clearer the algebraic solution.

The diagram is applicable, of course, to any units of length and of time, and any rate of acceleration can be represented by making the line AB the proper length.

For the case of a freely falling body the decameter (ten meters) and the second are convenient units.

THE USE OF THE JOLLY BALANCE IN CALORIMETRY EXPERIMENTS.

BY HARVEY L. CURTIS.

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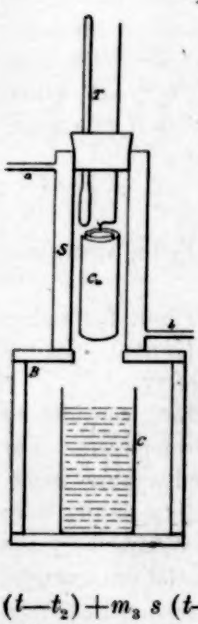
The object of this article is to show a method of determining the specific heats of substances as well as the heat of fusion and the heat of vaporization without determining the modulus of the Jolly balance. In order to make the student independent in his results, the specific heat of copper is determined first. The calorimeter is made of sheet copper, using as little solder as possible. One 2½ inches in diameter and 4 inches high is a very convenient size.

For heating the copper coil, I use the steam jacket, the principal features of which are shown in Fig. 1. This has been in use for many years, but it not described in any high school laboratory manual with which I am familiar. It consists of two cylinders of sheet metal, one within the other, and the space between air-tight except for the tubes *a* and *b*. Such a jacket will be made by any tinner for a few cents. The tube *a* is connected to some source of steam and the condensed water is carried off through *b*. The inner cylinder is closed at the top by a two-hole rubber stopper through which pass the thermometer *T* and a small copper wire, which suspends the coil *Cu*. The coil should weigh from 200 to 300 grams. The jacket is placed on a box *B*, which contains the calorimeter *C*, nearly filled with water. There is a hole in the top of the box, but the jacket is placed over it only while the coil is being lowered into the calorimeter. This should not be done until the temperature of the coil becomes stationary.



Then as the quantity of heat lost equals the quantity of heat gained $m_1s(t_1-t)=m_2(t-t_2)+m_3\,s\,(t-t_2)$ where m_1, m_2, and m_3 are the masses of the coil, the water, and the calorimeter, respectively; *s*, the specific

heat of copper; t_1, the temperature of the coil; t_2, the temperature of the calorimeter and water; and t, the resulting temperature. But if a_1, a_2, and a_3 represent the stretching of the spring of a Jolly's balance due to the coil, the water, and the calorimeter, respectively, and x the modulus of the balance, then $a_1x = m_1$, $a_2x = m_2$, $a_3x = m_3$. Substituting in the first equation:

$$a_1xs(t_1-t) = a_2x(t-t_2) + a_3x(t-t_2)$$

In solving, x disappears, and

$$s = \frac{a_2(t-t_2)}{a_1(t_1-t)-a_3(t-t_2)}$$

In determining the specific heat by this method it is necessary then to find the stretching for the coil, the calorimeter, and the water. This will require a heavier spring for the Jolly balance than is ordinarily used. It may be made of No. 18 spring brass wire, closely wound on a 3/8-inch rod, and should be about two or three feet long.

In determining the heat of fusion of ice, the same principle is used. If a_1, a_2, and a_3 represent the stretching due to the ice, the water, and the calorimeter, respectively; t_1, the original temperature of the water; t, the resulting temperature; and L the heat of fusion of ice, then $a_1xL+a_1xt = a_2x(t_1-t) + a_3xs(t_1-t)$, where x is the modulus of the balance and s the specific heat of copper previously determined. Solving,

$$L = \frac{(a_2-a_3s)\ (t_1-t)}{a_1} - t$$

The heat of vaporization may be determined in the same way as the last by substituting steam for ice.

In the last two, it is advisable to make corrections for radiation as indicated in Chute's Physical Laboratory Manual. In the first corrections for radiation are usually unnecessary.

The results obtained have been quite satisfactory, considering that we were compelled to use very ordinary thermometers. For the specific heat of copper three successive results were 0.095, 0.091 and 0.096. For the heat of fusion of ice like results were 78, 77.5 and 80.4. A part of these results was obtained by the students. For the heat of vaporization of water the only results so far obtained are 542.3, 527.8, and 543.3.

The method has little value for those schools which have

a sufficient number of balances capable of carrying as heavy a load as these experiments demand. It does afford an inexpensive method to those schools which are lacking in balances that will carry a heavy load.

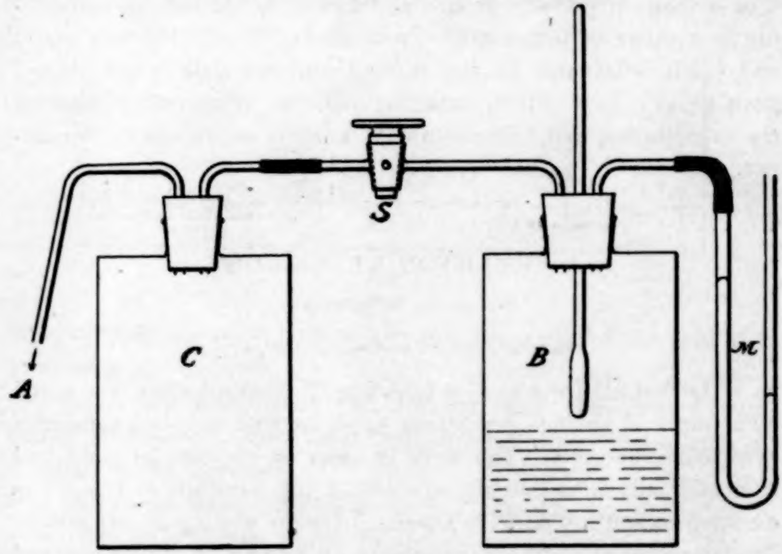
AN APPARATUS FOR DETERMINING THE RELATION BETWEEN PRESSURE AND BOILING POINT.

BY N. F. SMITH.

Professor of Physics, Olivet College.

The following simple apparatus has been found to give very satisfactory results in the hands of elementary students of physics.

A copper boiler *B* is provided with a stop-cock *S* to regulate the escape of steam, and an opening in the top into which a



rubber stopper can be tightly screwed. The rubber stopper carries a thermometer and a glass tube leading to a manometer *M* attached to the wall. A rubber tube leads from the stop-cock to another copper vessel *C* and thence to an aspirator *A,* which rapidly exhauts the air in *B* and *C.* The vessel *C* was introduced to equalize the pressure which, on account of variations in the water

pressure, was found to fluctuate slightly, and also to catch water which sometimes was forced back from the aspirator.

Under these conditions water in *B* can be made to boil under a pressure of from 20 to 30 cm. As soon as pressure and temperature have become constant, both are recorded. The stop-cock *S* is then partly closed so that steam is generated in the boiler faster than it escapes and the pressure thereby increased. By regulating the stop-cock the pressure can be kept constant at any point desired and readings of temperature made for every four or five centimeters increase in pressure. After the pressure becomes equal to that of the atmosphere the tube is disconnected from the aspirator and the pressure carried up as high as the strength of the boiler and the graduations on the thermometer will safely allow.

A range of pressure from about 26 cm. to 115 cm., corresponding to a range of temperature from about 70° to 110° was easily and safely attainable by the student and the data when platted gave a very good curve, bringing out the relationship between the vaporization and temperature of a liquid in an excellent manner.

A SKELETON TELESCOPE.

BY E. C. WOODRUFF.

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"Is that all there is to a telescope?" This question was asked by a pupil of average brightness when he first saw the apparatus here to be described. The work in class on the text in light had evidently only increased the mystery of the telescope to him. The question constitutes half the argument for the writing of this article. The importance of the experiments on images in telescopes and microscopes (No. 131 in Nichol, Smith and Turton's "Manual" and No. 82 in Ayres' "Manual") is emphasized by the same argument. The apparatus is intended to furnish a definite instrument for these experiments so as to avoid the use of pick-up pieces from the outfits of other experiments. It is also intended to be used in mirror and scale work (vid. School Science, Vol. II., p. 94,

April, 1902), where conventional reading telescopes are beyond the reach of the school. The design was originally in response to a definite request for such a device.

The construction is as follows (Fig. 1): *O* is an ordinary plano-convex lens of about 20 cm. focal length. *E* is such a double-convex lens as jewelers use—mounted, perhaps, in a flaring rubber tube *T*, and of about 6 cm. focal length. Used as a telescope the combination will have a magnifying power of about 3 diameters. *B* is a base board, 28x5x2 cm. *L* is an upright, 5x5x2 cm., screwed to *B* and carrying the eye-piece *E*. *S* is a similar upright carrying the object-lens *O*, but fastened to the side-bars *b*, one on either side of *B*, and so free to slide along the base. *C* is a cross-bar resting on top of *B* and holding the two bars *b* together. *W* is a wire, one end fastened to *B*, pointed at the other end, and bent at right angles

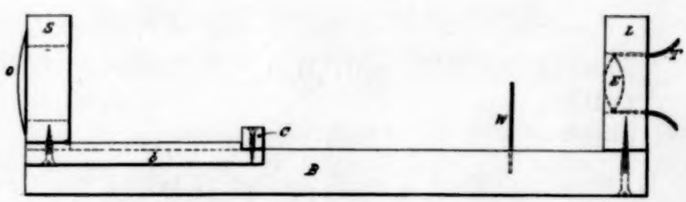

Fig. 1.

so as to bring the point horizontally into the center of the field of *E* to serve as a cross-wire.

Turn the instrument end for end and you have a compound microscope. The experiments are performed just exactly as directed in the Manuals.

Of course, when used as a reading telescope the definition is very good only in the center of the field, but that is all that is necessary. A dark cloth thrown over the instrument makes reading a little easier.

The simplicity of the arrangement appeals to the pupil. Many pupils will no doubt construct such instruments for themselves from reading glasses and hand magnifiers found lying around in most every house, thereby deriving considerable benefit.

EXAMINATION OF BAKING POWDERS.

BY WARREN RUFUS SMITH.

Department of Chemistry, Lewis Institute, Chicago.

Nothing interests the student in chemistry more than an opportunity to apply the knowledge gained in the laboratory to something with which he is already familiar. Unfortunately most of the commonest substances are of such complex constitution and composition that the elementary student can do little with them. I have found, however, that ordinary baking powders offer a field which is not beyond the skill and comprehension of the beginner. Below are some directions which students have used with satisfactory results. Of course these processes are not new and doubtless they can be improved. I offer them here simply to suggest to other teachers the possibility of similar experiments.

QUALITATIVE EXAMINATION OF BAKING POWDERS.

$NaHCO_3$	$KHC_4H_4O_6$	$KHSO_4$
$CaHPO_4$	$CaSO_4$	$KAl(SO_4)_2$
Starch	(NH_4) compounds	

1. STARCH. Treat a small amount of baking powder with cold water. Filter. Wash the undissolved residue, and boil it with water. Allow the resulting solution to cool and add a few drops of a solution of iodine in potassium iodide solution.

Blue or black color indicates starch.

2. TARTRATES. Treat with a small quantity of cold water. Filter, wash the residue with cold water. Evaporate filtrate and washings to dryness. Heat a small portion of the dry material. If tartrates are present, it will char and give the odor of burnt sugar. Moisten a small amount of the dry material with conc. sulphuric acid and heat.

Blackening indicates tartrates.

3. SULPHATES. Boil a small quantity of the powder with conc. hydrochloric acid till all dissolves. Dilute and add barium chloride solution.

White precipitate indicates sulphates.

4. Phosphates. Dissolve a small quantity of the powder in conc. nitric acid; dilute with two volumes of water. Put ¼ inch of ammonium molybdate solution in a test tube and add a few drops of the nitric acid solution. Warm and allow to stand.

A yellow precipitate indicates phosphates.

5. Calcium. Treat with dilute hydrochloric acid. Filter, add ammonium hydroxide in excess (testing with litmus), then add a very slight excess of acetic acid (litmus), boil, filter if necessary and add ammonium oxalate.

White precipitate indicates calcium.

6. Aluminum and Ammonium. Boil with sodium hydrate solution in a porcelain dish. If ammonium salts are present ammonia will be given off and can be recognized by its odor and effect on litmus. Filter the solution and acidify the filtrate with hydrochloric acid and then add ammonium hydroxide till alkaline.

White floating precipitate indicates aluminum.

DETERMINATION OF THE AVAILABLE CARBON DIOXIDE IN BAKING POWDER.

Arrange apparatus as in Fig. 1. *A* is a separatory funnel, *C* a dry 500 cc. flask, *D* a dry 2-liter acid bottle, *E* a liter flask filled with water, *F* a beaker, *G* a dry liter flask, and *H* a rubber tube. The rubber stoppers should be well greased. Weigh about 5 grams of powder in a test tube. Turn the powder into the flask *C* and weigh the tube again to get the weight of powder used. See that the tube *H* is entirely filled with water. Open the stopcock *B* and hold *F* so that the level of water in *F* and *E* is the same. Without altering the position of *F* close the stopcock *B* and pinch the rubber tube *H* tightly with the fingers. Remove *F* and replace it with the empty weighed liter flask *G*. Place *H* in the flask and release the pressure on *H*. Measure 100 cc. of water and put it in the separatory funnel *A*. Allow this water to run into *C*, closing the stopcock *B* just as the last of the water goes through and before any air enters the tube of *A*. Heat the flask *C* gently until its contents boil slowly for a few moments. If the contents of the flask foam, take away the burner before

the foam reaches half way up the flask. Allow to cool a little and then heat again. Do not let any foam reach the tube *I*. It has usually been boiled enough as soon as the tube *I* is hot from the steam in it. Allow the whole to cool to the temperature of the room, hastening the cooling, if convenient, by cooling *C* by setting a dish of cold water under it in place of the wire gauze. After *C* has apparently reached the temperature of the room allow the whole apparatus to stand for at least ten minues without further heating or cooling. Observe the temperature and the height of the barometer. Hold *G* so that the water in it is at

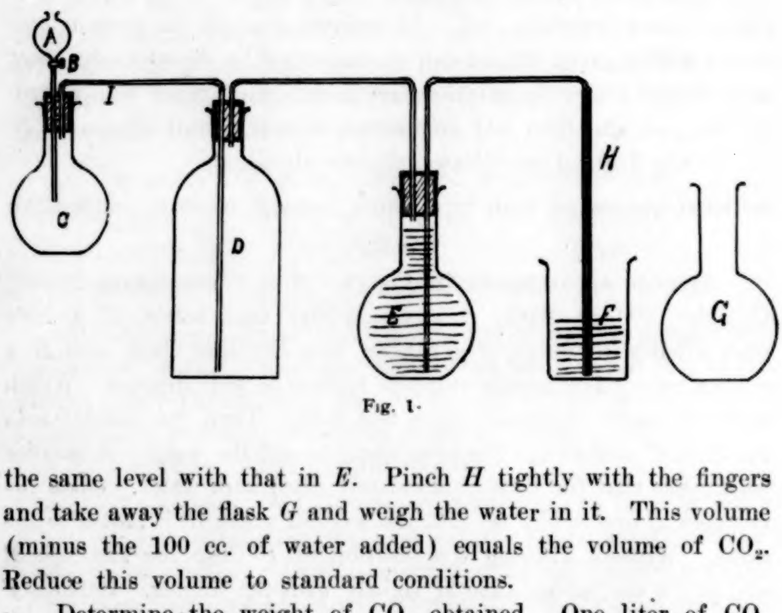

Fig. 1.

the same level with that in *E*. Pinch *H* tightly with the fingers and take away the flask *G* and weigh the water in it. This volume (minus the 100 cc. of water added) equals the volume of CO_2. Reduce this volume to standard conditions.

Determine the weight of CO_2 obtained. One liter of CO_2 under standard conditions weighs 1.977 g. Calculate the percentage of available CO_2 in the baking powder.

The greatest chances for errors lie in not having the apparatus tight and in not allowing to cool to the temperature of the room.

A COMBINED FILTER-FUNNEL AND BEAKER.

BY GEORGE GEORGE.

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In Fig. 1 is shown a piece of apparatus which the writer has found very serviceable in large classes in elementary chemistry, especially in experiments where precipitation, filtration and weighing are combined, as, for example, where a comparison is made of the weights of different metals replaced from their salts by a certain weight of another metal. As can be seen from the sketch, it is really a large thistle-funnel, *A*, having a bulb *B* and a short stem *C*, which can be closed by means of a piece of

Fig. 1.

rubber tubing *D* and glass rod *E*. The diameter of the large bulb *A* is from 6 to 8 cm., its capacity about 100 cc., and its weight less than 20 g. These can be made by anyone rather skilled in glass blowing.

Use of the Funnel.—Suppose the experimental problem to be: "To determine the equivalent of silver by finding the weight of the metal displaced from a solution of silver nitrate by a known weight of magnesium."

The clean and dry funnel (without the rubber tubing and glass rod) has its bulb *B* lightly stuffed with *dry* glass wool, and is then carefully weighed. It is then supported on a ring of a retort stand and the stopper *DE* placed upon the stem. A strong solu-

tion of silver nitrate is placed in *A* and then a weighed piece of magnesium (about 0.01 g.). This is stirred about with a glass rod so as to remove the silver from the ribbon as fast as it is deposited. When all the magnesium has disappeared, the stopper is removed. As the solution runs out, the precipitated silver is retained by the glass wool in *B*. After well washing the metal, the funnel is placed in a drying oven or on a sand bath to dry. On weighing the funnel with the silver, the weight of the precipitated metal is found and its equivalent calculated. For example:

Weight of magnesium used	= 0.104 g.
Weight of funnel alone	=17.215 g.
Weight of funnel + silver	=18.156 g.
Weight of silver	= 0.941 g.

Accordingly, 0.104 g. of magnesium has displaced 0.941 g. of silver, and since the equivalent of magnesium is 12, that of silver is $0.941 \times 12 \div 0.104 = 108.1$.

In a similar manner the equivalents of other metals can be determined, it being necessary in some cases to use *hot* solutions in *A* and in the case of an easily oxidized metal (*e. g.*, copper) it is as well to aid the drying by washing it with a little alcohol and ether.

Numerous other experiments can be performed by means of this simple piece of apparatus, which under ordinary circumstances could not be undertaken by *beginners*, owing to the great manipulative skill required, but the results of which are of great educational value when "discovered" by the pupil. Thus, one can set a class of 30 pupils to work to find out the equivalent of chlorine by dissolving a known weight of silver in nitric acid, and precipitating the metallic chloride in the funnel, and on comparing the results it will be found that the equivalent obtained by *each* pupil is the same within less than one per cent of error.

A SIMPLE AUXANOMETER.

BY L. MURBACH.

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Many simple auxanometers have been devised for recording the growth of a plant at all hours of the day.* Perhaps it will be sufficient to state that simplification of apparatus, so as to

***Ganong's Plant Physiology, 1901, p. 105, refers to a number of these, and choice may be had among them.**

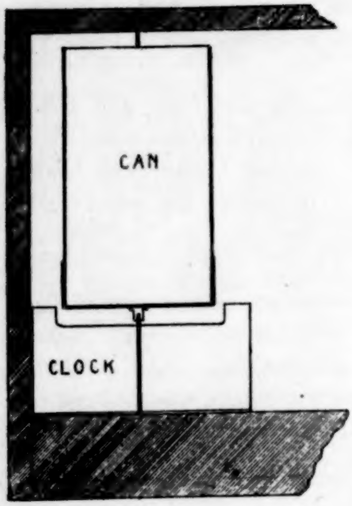
make physiological work possible in more secondary schools, is the chief reason for giving this description of a boy's-made auxanometer. So far as I know, none of those described can be made by boys or an inexperienced teacher.

The boys were given a rough sketch, the materials, and a description of what was wanted. After the apparatus was completed and in use, a first-year student in the Drawing Department made the working drawing here presented. Of course, the wood-work was somewhat rougher than sketched, but this was no serious drawback.

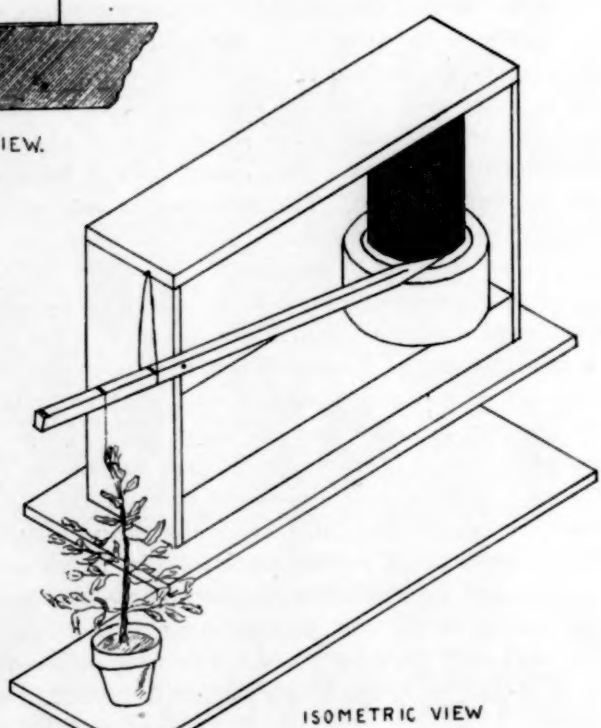
The materials necessary for the device are some pieces of ¾-inch boards (ours were from a soap box), nails, a cheap nickel day clock, an empty one-pound baking powder can. First, the button on the back of the clock, for turning the hands, was soldered to the middle of the cover of the can. Then a tack or small nail was soldered to the middle of the bottom of the can. This formed the cylinder upon which the blackened paper is carried.

The boards would better be cut or split about as wide as the diameter of the clock. Two pieces are cut fourteen inches long for the top and base. The base may be doubled or nailed to a heavier baseboard for stability. In the former case it will appear 1½ inches thick as in the sketch. Next two end pieces were cut 9 inches long—enough to make an oblong frame, with the top and base board so that the cylinder on the back of the clock may stand in one end of the frame. When the frame was nailed together this end of it was left open at one joint so as to raise the top for putting the clock (on its face) and cylinder in place (see sectional view). Just where the nail or tack in the top of the cylinder came, a hole was bored through the top-board for the insertion of the nail; this keeps the cylinder upright while the clock rotates it. A pointed marker twelve inches long and ¼ inch in diameter was cut from thinner boards and pivoted to about the middle of the end of the frame opposite the end in which the clock and cylinder stand. The hole in the marker for the pivot should be ¼ the length so that the record is magnified three times.

The marker must be put on that side of the frame that will insure the cylinder being turned away from it by the clock, other-



SECTIONAL VIEW.



ISOMETRIC VIEW

wise the point of the marker will catch on the blackened paper of the cylinder and stop the record. With several notches cut on the end of the marker it is adapted for plants differing in their rate of growth. The elastic band outside the pivot of the marker is to take up the slack caused by the growth of the plant and thus to move the marker down the cylinder as fast as the plant grows. (See figure.)

When the clock is wound and in place some paper is pasted on the tin cylinder. This may be easily smoked from the flame of a piece of candle wicking that has been dipped in coal oil; if one application is not enough a second dip will insure a more uniform coat. A twirling motion of the cylinder, while holding the end pivots between thumb and fingers, will bring about the best result in the least time. After the cylinder is carefully placed in position the time of starting should be marked by a short vertical line and the plant immediately attached. Where it is possible the temperature should also be noted as often as possible and recorded on the line just outside the point of the marker.

When the record is complete it may be fixed while on the cylinder with shellac fixative and may then be preserved for future reference. Any writing to be done on the record must, of course, be done before the fixing.

The clock with the cover of the baking-powder can may be also used as a sort of clinostat as shown in the upper figure. A small pot of seedling morning glories, placed in the cover and one placed by the side for control will show the phenomenon of heliotropism nicely. Then if some germinating peas are pinned to a cork or to a piece of circular, soft-wood board, and some wet sphagnum or sawdust placed over them and the whole fitted into the tin cover, the effect of rotating the seedlings in a vertical direction may be observed. A few experiments may be necessary to find seeds or temperature such that the root's rate of growth and the rate of movement of the clock are about the same. Very satisfactory results have been obtained in this way without changing the rate of the clock. A very simple, though not as satisfactory way, is to remove the glass in the front of the clock and tie a small vial filled loosely with soaked morning glory seeds and sawdust, to the minute hand, lengthwise, but as near the pivot as possible.

Metrology.

TEACHING OF THE METRIC SYSTEM *

BY WM. F. WHITE

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IN GRAMMAR SCHOOL AND HIGH SCHOOL

First let us consider the pedagogical problem that presents itself to the teacher of the high-school class or advanced grade in the grammar school taking up the metric system for the first time.

There should not be any need for the remark that it is absolutely necessary for the teacher of the metric system (or anything else) to understand it himself first. A man who can not estimate his own weight in kilograms with some approach to accuracy, who does not know whether a sheet of letter paper is twenty millimeters wide or twenty centimeters or twenty kilometers, who is dazed by the question how many liters a given bucket will hold, is not prepared to teach the metric system with success, even if he can recite all the tables without looking on! The need for this caution is the less excusable from the fact that the theory of the metric system can be mastered by any intelligent person of adult age by an hour or so of attentive study, and he may familiarize himself with the metric units by actually using them for a short time. Estimate in terms of metric units, and then weigh or measure. Get a metric folding pocket rule, carry it, and use it. You will soon find it so handy that you will prefer it. For small weights remember that a new 5-cent nickel weighs 5 grams.

The metric system is essentially a *decimal* system, and it must be ascertained at the outset whether the class has a working knowledge of decimals. No doubt every pupil has "passed out of decimals"; but how much did he take along with him when he passed out? A test recently made with eighty men and women not em-

*This article is not written for science teachers who, constantly use the metric system and need no advice as to the teaching of it, but for teachers of the metric system in arithmetic classes.

ployed as teachers or accountants showed that only thirty-six could perform a very simple operation in decimal fractions. Even of this number sixteen preferred to use "common fractions," although in the particular example chosen that method involved more work. Forty-four persons, or 55 per cent of the whole, were helpless in the presence of decimal fractions of the simplest sort. But of the eighty asked, all but four were able to work the example by "common fractions." Some significant remarks were reported from this test. Two who used "common fractions," said: "They are easier than decimals. More attention was given to them in school." Another did not seem to know what was meant by decimal fractions. One man who could not use decimals declared he had "a book that tells you all about it!" Another could do it if it were given in dollars and cents. The number of persons involved in this test is too small to warrant any general conclusions; and every schoolman trusts that the boys and girls today are receiving a very much better training in decimals. Still it will hardly be questioned that decimal fractions are generally not taught or understood as well as "common fractions." What is popularly known of decimals in the United States has been learned largely through the use of our decimal coinage. Europe learned decimals by using decimal weights and measures as well as coins; and the school boys of this country can learn in the same way. That is, by learning and using the metric system they can get a working knowledge of decimals. But the teacher should know early whether decimals are to be learned through the metric system or whether such knowledge is already on hand at the beginning as an asset.

But given a teacher that can use the metric system and a class that can use decimals.

Although the metric system is perhaps easier to learn than anything else that may be called a system, it presents to the beginner two difficulties, both of which, however, can be quickly removed. To secure this result, is the task to which the teacher addresses himself at the start. The two difficulties are, (1) the pupil's *belief* that the learning of the metric system is hard, and not worth while, and (2) the strangeness of the *names* used. Let pupils understand from the first that the metric system was invented in the interest of simplicity, and is as much simpler than

the English, or "customary," system of weights and measures as our decimal money system is easier to learn and use than the English system with its pounds, shillings, and pence, and for the same reason, because it is *decimal*. Let them know also that its simplicity and practical utility have been recognized by people everywhere until now the metric system is the system in common use in most civilized countries and is almost universally used in science. The strangeness of the terms employed would soon wear away, but may better be removed at once by calling attention to the same prefixes with the same meaning in other and familiar words: *Dec*ade, *deca*log, *hecto*graph, *deci*mal, *cent*ennial, *cent, mill,* etc. Also *mete*, gas *meter*, water *meter*, etc. The terms that are used the pupil must have on the end of his tongue; and when spoken by another, they must instantly call up the idea. *Kilo* must mean thousand as much as the word *thousand* or the number 1000.

The writer would favor the spelling *hekto-, deka-, meter, liter, gram* (instead of *hecto-, deca-, metre, litre, gramme,* the last three of which seem especially objectionable.)

The metric abbreviations adopted by the International Bureau of Weights and Measures are also the abbreviations used by the United States Bureau of Standards and by the government printing office. There can be no question as to the advisability of the teacher using these in preference to the various abbreviations found in some text books. The list of approved abbreviations and any other information on the metric system that is desired may be had for the asking from the Bureau of Standards, Washington, D. C., the recognized and official authority on metrology in this country.

It is often best, especially with children, not to introduce all the metric terms at first. And in the problems, and the class work generally, let those units be most used which are oftenest used in science and commerce.

MUST BE TAUGHT FROM WEIGHTS AND MEASURES THEMSELVES

The one mistake oftenest made in the teaching of the metric system, and by far the most serious mistake, is in teaching the metric units through their English equivalents instead of from the metric weights and measures themselves. So long as a boy,

or a man, thinks of a meter as 39.37 inches, so long the metric system will remain a foreign language to him. For the teacher to so present it, is to court failure. Let the meter stick be in the hands of the pupils, and have them measure with it. Later the liter can and the 10-gram weight, the 100-gram weight, the kilo weight, etc. Teach the metric system as if it were the only system of weights and measures in existence. In this way the metric terms soon come to have a distinct and vivid meaning in the pupil's mind—vivid because derived from experience.

ENGLISH EQUIVALENTS

After the metric system has been well learned by itself, is the time to institute comparison with the customary system, deriving equivalents, and converting weights and measures from one table to the other. Then the comparison is an excellent review of both the metric system and the English. High-school pupils should be able to use exact equivalents when desirable; but all students derive most benefit from having many problems in conversion to be solved by the use of equivalents that are easy approximations, often allowing of mental reduction. It is better that the student know and use a few such approximate equivalents as the following than that he attempt only the use of the exact values and remember none.

1 inch	and	25 mm	1 meter	and	40 inches (exactly, 39.37)
1 foot	"	30 cm	1 kilometer	"	0.6 mile
1 yard	"	0.9 m	1 liter	"	1.05 qt.
1 mile	"	1600 m	1 hl	"	2.8 bu.
1 quart (U. S. liquid)	and	0.9 liter	1 gram	"	15 grains
1 peck	and	9 liters	1 kg	"	2.2 lb. (avoir.)
1 lb. (avoir.)		0.45 kg	1 metric ton	"	2,200 lb.
1 ton (U. S. 2 000 lb.)	and	0.9 metric ton			

APPARATUS FOR TEACHING THE METRIC SYSTEM.

Full sets of apparatus especially designed for teaching the metric system are kept for sale by only one house—so far as the writer has ever been able to learn—the Library Bureau, main office 530 Atlantic avenue, Boston. These sets are attractive and very helpful. But many schools will desire to avoid the expense of purchasing a set; and the expense is not necessary. But it *is absolutely necessary that metric weights and measures be in hand and used.* These can be made by the pupils themselves. If possible a good metric chart (such as one of the American Metrolog-

ical Society's or the Library Bureau's) should be procured and kept hanging on the class room wall throughout the year. Beyond this, there need be almost no expense.

Rules—3 dm on one edge, 12 inches on the other—retail for one cent. A meter stick may be made by marking the graduations on a light moulding or a well-planed scantling. A good maple stick is preferable. It is well to cut the lines in with a sharp knife and then run over them with pen and ink. This secures clear, sharply defined, permanent lines. A neat little rule—say 10 cm long—may be cut from cardboard.

A cubic centimeter cut out of wood or other material may be required of each pupil, to give him a definite idea of this important unit.

A cardboard liter box, cubical, each of the three edges that converge in one corner graduated to cm, and one of the faces divided by lines into 100 cm^2, pictures to the eye 1 dm^3, made up of 1000 cm^3, and shows the relations between the tables of length, surface, volume and capacity.

It is often an economic arrangement to let the boys produce the meter stick and the wooden cm^3, and the girls the cardboard rule and liter box. The girls have made paper boxes in their play and need but little instruction about the making.

To hold water—necessary in gaining acquaintance with the capacity measures and especially in showing the relation to the table of weights—tin capacity measures are needed. Cans may be labeled with size, date, and student's name. It is desirable to have measures illustrating the liter and several of the commoner fractional parts of it. Some three-pound tomato cans are fair approximations to one liter. A $1\frac{1}{2}$ pound corn can is close to the half liter. A condensed milk can was found to approximate the quarter-liter; and a quarter pound deviled ham can, the deciliter.

A good balance is too difficult for children to make. If the school does not possess a scale, one can usually be borrowed; but a spring scale or steelyard, or any form of scale depending on an arc or arm graduated to the English system, is manifestly not desirable.

For small weights, the most convenient material is lead in

the form of printers' space lines. Use the thick leads, called "slugs." They can be cut with old shears, and the name of the weight can be scratched into the lead. For larger weights, perhaps the handiest device is to load small baking powder cans with pebbles or shot.

Among the weights needed is one equal to the weight of the empty liter can that is used to show the relation, 1 liter of water weighs 1 kg. (Though, in strict accuracy, the liter is defined as the volume of a kilogram of water weighed under standard conditions, and in the nature of things can be only a very close approximation to the cubic decimeter, the teacher would best neglect that distinction, and present as above, which is also the historic method of approach.)

Not all of the apparatus need be made by the pupils of any one class. They take pride in their work if it is known that, of all that are made by any one class, the best specimens are to be retained as part of the school's permanent equipment.

Class-made apparatus is not accurate. But it is sufficiently so for the purpose; there is often a choice between that and none; and the making of the apparatus is no small part of the training.

UTILITY OF SYSTEM SHOWN TO PUPILS.

Students can not be expected to long retain interest in anything whose utility they do not see, or in which they do not soon acquire some degree of proficiency. For this reason, the first table that is taught should be used and made an effective instrument before the second is presented. Students should see clearly that metric reduction is only moving the decimal point. *E. g.*

m	dm	cm	
2	5	8	= 2.58 m = 25.8 dm = 258 cm = 2580 mm
m		cm	
4		9	= 4.09 m = 40.9 dm = 409 cm = 4090 mm

When, after a few minutes practice, such reductions can be made mentally, instantly and correctly, let some of the class take an example in reduction in the English linear table (such as yards to inches, or inches to yards) and others of the class take one in the metric table (as above), and let them compete, both as to speed and accuracy. When they have changed about and all have become convinced that the metric system is a timesaver—is the school boy's friend—then the teacher's work is

half done. Such an exercise should be reached before the close of the second recitation period.

REVIEWS

Such a course as that suggested above might take two weeks of the class's time usually given to arithmetic. The students should then be able to use the metric system much better than they can ever use the English system. But, like any other subject, the metric system must be reviewed to be kept. Better than to learn it, drop it, and later review it, is to have it kept in the mind by frequent use, later problems in arithmetic and the work in science making it part of the pupil's permanent mental outfit.

METRIC SYSTEM IN THE PRIMARY DEPARTMENT

The foregoing suggestions are to grammar-school and high-school teachers of arithmetic. But when the metric system becomes the only American system of weights and measures, it will of course displace the foot rule, the quart can, and the pound weight in the primary school. The children will use *meter* and *centimeter, liter* and *centiliter, gram* and *kilo.* These will be sufficient for them. The other metric terms can be added later one by one as needed. The system will be very concrete, will be kept in use in every grade and every day, and, displacing the hard tables of the present customary "system," will save much time in the pupil's school life for useful pursuits.

IN BRIEF

1. Remove impression that metric system is difficult, and create interest in it.

2. Teach it independently of the English system. Then review both by problems in conversion.

3. Use caution in introducing metric terms—not too many at a time. Avoid needless complication of the nomenclature.

4. Place the emphasis on those denominations and those applications of the system which are oftenest met in science and commerce.

5. Make clear the advantage of a decimal system, both theoretically and by early and frequent practical application and comparison.

6. *Have the weights and measures in hand, and see that they are used. Teach pupils to think in metric terms.*

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

BIOLOGY.

In the report of the Pittsburg meeting of the Botany Club of the A. A. A. S., there are several titles that interest teachers of biology. They are: "Notes on Material for Class Demonstration," by Mel T. Cook, and a cheap and convenient laboratory aquarium, museum methods and demonstration of life-histories by Dr. F. E. Lloyd.

The strength of ants is strikingly shown by Armand Miller in a three paragraph note in *Science,* Sept. 26, where he tells about his surprise on weighing an ant and the burden she was dragging—a grasshopper. The ant weighed 3.2 mg. and the grasshopper 100 mg. Would it not be a remarkable man who could drag a 4½ ton load?

That the water or land form of the leaves of Proserpinaca palustris is due to the amount of water in the protoplasm, is shown by McCallum in an interesting preliminary paper in the August number of the Bot. Gazette. Transpiration is checked in the water and facilitated in the air. After excluding the factors CO_2, O, light, nutrition, temperature, salts, etc., the contact stimulus was eliminated by finding that the water form of leaf was developed in moist atmosphere. The author then clinches his conclusion by growing the land form of leaf in a culture which withdraws some water from the protoplasm of the plant.

School instruction in the effect of stimulants and narcotics as given in a "preliminary report" in *Educational Review,* June, is of interest to physiology teachers. It is made by a committee of the New York State Science Teachers' association. Standard and school texts are compared in parallel quotations; questions sent out to teachers in the state and the answers received are given. Nine conclusions are drawn, the most important being, that "the evils of alcohol and narcotics can be presented most effectively from the moral and economic point of view." The report closes with four recommendations, two of which might serve

the teacher as precepts what to teach. In a later number the *Educational Review* refers to a long reply to this report issued by the New York State Central Committee for scientific temperance instruction which the editor recommends procuring and reading, though he does not at all indorse it.

A Simple Atomizer.—When the laboratory atomizer cannot be found for fixing a drawing or chart, a very simple atomizer may be easily constructed. Find two glass tubes, one an inch taller than the bottle containing the shellac, the other any convenient length to blow through. Draw each to a point in the flame, leaving a little larger opening in the blowing tube than in the upright one. Put the shorter tube into the bottle, then blowing a stream of air over the point of this tube will produce the desired spray. To give greater stability the tubes may be held at right angles to each other through perforations in a cork, a quadrant of which has been removed where the tubes are to meet. A rubber bulb may serve as a blower.

"For successful investigation," says Professor O. F. Cook, of Washington, in *Science*, Oct. 3, "the first and most essential preliminary is an interest in the question. The investigator, like the author, must first be born. His training determines the degree of excellence. No amount of training can remove organic defects, but bad training may be worse than none in lessening the attainments of the most capable. The investigator must not only be born, he must be allowed to grow up." * * * "It is not strange that after youth consumed in our modern and efficient system of kindergarten, primary, grammar and high school, college and university, the graduate and even the post graduate continues to expect somebody to tell him what to do next."

L. M.

CHEMISTRY.

Carbon Bisulphide is now manufactured on a large scale by electrochemical means, being produced by direct union between the vapors of sulphur and carbon in an electrical furnace.

Silicides of the Alkaline Earth Metals, $CaSi_2$, $BaSi_2$ and $SrSi_2$, analogous to the carbides, CaC_2, etc., are now being manufactured by heating in an electric furnace, to a temperature higher than that needed for carbides, a mixture of the carbonate, oxide, sulphate or phosphate of the metal concerned with silica and enough carbon to effect the reduction. These silicides are crystalline and of a bluish-white color. They react with water to give hydrogen, one pound of calcium silicide yielding, in a

common acetylene generator, 18.5 cubic feet of pure hydrogen. These qualities suggest a field for generating hydrogen in the laboratory or for ballooning purposes. Barium silicide has the property, if put into molten iron or steel, of combining with the sulphur and phosphorus therein, removing them in the slag as barium sulphide or phosphide. They are also good reducing agents, working in either acid or neutral solutions.

The Uses of Barium Hydrate, now that it can from improvements in its manufacture by electrochemical processes be placed on the market at as low a price as 3 cents per pound, are increasing with astonishing rapidity. It is used "in the paint trade, for making white paints; in the sugar trade, for recovering sugar (as insoluble barium saccharate) from waste dilute solutions, and for softening boiler waters. The mother liquors from the crystallization of hydrate, containing barium sulphide and sulphydrate, have been found useful in removing hair from hides, a solution diluted to 2½ per cent, removing all the hair from a hide in 3½ hours' immersion, without any injury to the leather. The same solution is very suitable for preparing the white paint called "lithophone," which is made by running a solution of zinc sulphate into barium sulphide solution, thus producing the precipitated pigment, a mixture of barium sulphate and zinc sulphide. The mother liquors can also be converted into barium carbonate, which has found application in the cyanide industry and also in the manufacture of bricks; for mixed in small proportion with the clay, it is said to prevent red bricks from turning white and white bricks from turning green."

Electrochemical Industry, I. p. 18.

Water of Crystallization.—In testing salts as to whether they contain water of crystallization or not, it is a common procedure to heat them in test-tubes. Even when great pains are taken to keep the mouth of the test tube lower than its closed end so as to prevent the expelled water from running back on the hot glass and thereby breaking the tube, the mortality rate of the tubes is not inconsiderable. By the following modification of the experiment a greater degree of success is attained. A little frame of iron wire is made and placed upon a wire gauze (best of copper, as a flame strikes through an iron one too easily) supported on a ring stand. This frame is of such a shape that it supports the closed end of a 4-in. test tube about a centimeter above the gauze while its open end projects a little beyond the gauze. A flame is placed under the gauze and so regulated that it heats red-hot a spot of it 2 to 3 cm. in diameter. The salt placed in the tube is thus uniformly and moderately heated and gives off its crystal water with no danger of its running back and breaking the glass.

A frame can be arranged so that three or four test tubes can be placed at once on the gauze, their closed ends converging to a common center beneath which the flame is placed. In this way several salts can be under observation at the same time, whereby not only is time saved, but also a stricter comparison of the behavior of the salts is made possible, so that it is unlikely that the student will mistake mechanically enclosed water for water of crystallization.

Book Reviews.

Essentials of Chemistry. By JOHN C. HESSLER, PH. D. and ALBERT L. SMITH, PH. D. 13x19 cm., xxi+405+96+xx pages. Benj. H. Sanborn & Co., Boston, 1902. $1.20.

This book represents a decided advance in the teaching of elementary chemistry. The authors, recognizing "the fact that the terms and ideas of Chemistry are *outside of the common experience*, and that it is useless to expect the pupil to grasp theoretical conceptions before he has become acquainted with the fundamental phenomena of the science," have arranged the sequence of topics so that the student is led gradually and logically up to a knowledge of the best sort of chemistry. They have had in mind continually the limitations of both pupil and teacher and have produced a book that is modern and scientific, yet not too difficult.

The treatment of the subjects of equilibrium, mass action, dissociation and ionization has been accorded the place it deserves. The chemical equation also has been presented, with its limitations made clear, and there is no danger that the pupil who studies this book will get the notion that chemistry is the science that treats of atoms.

The laboratory course, designed to accompany the text, is placed at the end of the book. The experiments are simple and well chosen, and the directions for their performance show that they have been repeatedly tested and worked over.

Taken all in all, the book is admirable, and its use cannot but contribute greatly to lifting the study of chemistry up on a higher plane than it now occupies.

C. E. L.

Physiology by the Laboratory Method for Secondary Schools. By WILLIAM J. BRINCKLEY, PH. D. 13x21 cm., xvi and 536 pages. Ainsworth & Company, Chicago, 1902. $1.25.

In no recent textbook of physiology has there been so clearly illus-

trated the effect of modern methods on scientific teaching as in this; even its title suggests the radical change which has taken place in the character and scope of the instruction during the last decade in this somewhat neglected branch of science. Its initial impression on the reader is in line with this, tempting one to a hasty review of the various textbooks of physiology now in use in our high schools, and the striking difference between them and this one, both in subject matter and manner of treatment. Such a review would prove advantageous to Mr. Brinckley's book as regards many of its features, and could not help suggesting upon how much firmer a foundation physiology stands today than a few years ago.

Briefly outlined, the plan of the book is as follows: An introduction which relates the human body to other bodies, followed by an analysis of the elements of the body considered microscopically. The first system introduced is the muscular, and in this section is an excellent reference table of the principal muscles. This is followed by a discussion of the nervous system. The text in connection with this is very full, and the diagrams of nerve-tracts deserve special mention.

It seems a little unusual that the subject of the skeleton is placed between a section on nerves and on digestion, but its position is a matter of secondary importance.

Digestion and kindred topics (circulation, metabolism, etc.) are very thoroughly considered, much space being given to experiments on foods.

After a discussion of the ductless glands and the special senses, the remainder of the book, constituting about fifty pages of Appendix, is given over to the discussion of histological methods, directions for the use of the microscope, poisons and their antidotes, and diseases and their prevention. This section is taken largely from the Michigan State Board of Health bulletins. Last of all is a chapter on First Aid to the Injured. The text is followed by a glossary and index.

The amount and detail of the work render it unsuitable for use in the lower grades in which physiology is frequently taught in our public schools. It may be used by judicious selection of experiments in schools where the subject is taught in the senior year, but would seem to be of more value in normal schools and colleges, to which it seems specially adapted.

It is a valuable reference book for any teacher of physiology, not only on account of the text, but also for the suggestiveness of the experiments. The illustrations are very numerous and clear, the colored plates being especially fine, which, with the tables of muscles, nerves, etc., constitute a striking feature of the book.

Whether it is possible for secondary school teachers to make use of the book or not, it deserves wide recognition among them as evidence of a decided change in the scope and aims of the teaching of physiology.

GRACE F. ELLIS.

The Science of Mechanics. By Dr. Ernst Mach. Translated by Thomas J. McCormack. Second Revised and Enlarged Edition 13x19 cm. and xx+605 pages. The Open Court Publishing Co., Chicago, 1902. $2.00.

The subject of Mechanics is usually regarded as the driest and hardest of physics. Text-book writers in their efforts to cover the whole field of physics and to present the more modern developments in a volume that is to be designed for a single year's course in our schools have condensed the subject of Mechanics so much that little more than dry dust and bones are left. The pupil struggles through this in hopes (buoyed up often by the teacher's assertions) that the other parts of physics will prove more atractive. Now this teaching of mechanics can be made vastly more profitable and interesting if its history and development be introduced. The very methods of discovery employed by the pioneers in the science are usually the best methods for presenting the subject to the learner. They may seem more clumsy and roundabout than those now prevalent, but for that very reason they are the more readily comprehended by the immature mind. A humanistic touch here and there helps wonderfully in arousing attention and sustaining interest. Now there is no excuse for not applying this historical method to some degree at least. The book under review is a masterful presentation of the subject of mechanics, much of it being not too hard for the beginner. It is "a critical and historical account of" the development of the science of Mechanics. The author puts us in direct personal contact with the discoverers of the principles of the science. He makes us appreciate their difficulties and shows us how they were surmounted. We see what this man and that contributed to the progress of the science. We learn how the science came to be what it is now. As said above, much of this matter can be told the beginner in the course of the study and its value thereby much enhanced. No teacher can afford not to carry along some course of reading in line with his work, and certainly the perusal of this book will improve the teacher and his work as much as anything can. The book cannot be too highly recommended.

C. E. L.

The Teaching of Chemistry and Physics. By Alexander Smith, B. Sc., Ph. D., Associate Professor of Chemistry in the University of Chicago, and Edwin H. Hall, Ph. D., Professor of Physics in Harvard University. 14x20 cm., 377 pages. Longmans, Green & Co., New York, 1902. $1.50.

This is a volume in the American Teachers' Series, edited by Dean James E. Russell, of the Teachers' College, Columbia University. It is composed of two distinct parts, one on Chemistry, by Dr. Smith, and the other on Physics, by Dr. Hall. According to the Editor's Note, "the authors of the separate parts have conferred frequently during the progress

of the work, and have endeavored to avoid unnecessary duplication. There are thus some subjects of equal importance to teachers of chemistry and physics which are discussed in one of the sections only. In a few instances, however, the divergence between the opinions of the authors seemed to make it desirable that each should present his own. It has been deemed better to have a logical presentation, even at the risk of disagreement, than to give the impression that there is only one way of conceiving or giving class instruction."

The authors' division of this book into two distinct parts makes it desirable to review it as if it were two books. Accordingly, the review by the undersigned will be devoted solely to the 227 pages covered by the Chemistry.

The reviewer has read this book with profit, satisfaction, and dismay. With profit, because he found much he could use; with satisfaction, because he found much he already was using; with dismay, because he found much he had never used. A second examination of many parts shows that the author has thought out to a working solution many problems seldom considered by most college teachers of general chemistry, and, of course, not comprehended by most secondary teachers, because the secondary teachers were once students of these very college professors. With all kindness, it must be said that many of the shortcomings which Dr. Smith lays upon the shoulders of high school teachers go back to the college course in chemistry, with its dogmatism, vagueness, lack of unity, incompleteness, and sterility. But the high school teacher has no longer any ground for ignorance of the pedagogic side of chemistry, for Dr. Smith has supplied the very book we have all so long awaited. There is no longer any ground for ignorance, I repeat, because this book commands attention, inspires confidence, literally sweeps away many traditional difficulties. It is a vital, human, sympathetic book, destined to outlive many a contemporary textbook.

The author utilizes many current sources of information—both American and English—but he has generously given credit in most instances. Indeed, these direct citations are a prominent feature of parts of the book, and, together with the bibliographies, they contribute largely to the permanent usefulness of the book as a whole. The references serve to elucidate the points of the author, and are not to be understood, as he himself says, "to indicate emphatic approval of those works as wholes." In some instances Dr. Smith judiciously leaves the reader "to reach a decision for himself."

The Introduction presents some reasons for the study of science, a brief history of chemical instruction, and a consideration of the present condition of chemistry teaching. Regarding the last point, he says (p. 27): "At present the average instruction in chemistry does not even remotely approach, in the benefits which it gives, the best that can be given or is given." This is doubtless true and would be depress-

ing if this very book did not contribute effectively to the attainment of a more desirable end.

As to the place of chemistry in the curriculum, the author believes (1) "physics must come first" (p. 33), (2) "probably at least twice as much can be done in the fourth year as in the first, on this account alone" [general advancement of the pupil] (p. 37), and (3) "many bodies of recognized authority incline to recommend the placing of chemistry late in the course" (p. 39).

Under the rather narrow title, "Introduction of the Subject," the author discusses some impediments to be overcome in teaching science, the character of introductory work, the three general classes of text books, generalizations of a qualitative and a quantitative nature, and the relation of quantitative laws to formulæ and equations. The last two points deserve emphasis. Dr. Smith makes it very clear that quantitative work of a simple, but judicious, nature should be a part of the early work, and that the pupil should be taught that weight is the only physical property of matter which it preserves in chemical transformations. Incidentally, he cites (p. 74) a simple experiment to illustrate multiple proportions. Pages 77 to 84 should be read and pondered over by every teacher of chemistry. They cover the interpretation of quantitative data, and are too long to quote. The main point is, "the equation can never be understood unless a quantitative measurement is brought to the notice of the pupil, its numerical result seen, and its translation into the form of an equation exhibited." And the reviewer believes that the pupil should make this measurement. The author further says (p. 83): "In view of the fact that equations, symbols, formulæ, etc., are not parts of chemistry, but our mode of recording chemical facts, it seems desirable to plant the facts and their importance securely in the mind of the pupil before these conventions are considered. Since they are quantitative expressions, they cannot logically appear before the method of measurement has been explained." We are under deep obligation to Dr. Smith for emphasizing this relation of fact and theory, and especially for the concrete illustration given on pages 78 ff., showing the logical relation between experiment and equation.

In the fourth chapter the author discusses instruction in the laboratory. Here again we have a wealth of suggestions, fresh from the keen mind of a teacher who realizes the place of laboratory work, for he says (p. 91) "the course should be arranged round the laboratory work, and the latter should carry the thread of the subject." He rightly emphasizes the importance to the teacher of a knowledge of the psychology of laboratory work, discusses fully the essential features of laboratory directions, the attitude of the pupil, and the necessity of teaching laboratory technique early in the course. This chapter also contains a helpful discussion of the value, limitations, scope and applications of quantitative work. It is one of the most helpful parts of the book. The author's

position on this subject may be judged from the following: "We have already referred to the emphasis which is necessarily laid in chemistry upon quantitative measurement and the interpretation of the results. Imaginary examples, as we have hinted (p. 80), may serve when actual ones are not available, but the ease with which properly chosen measurements can be carried out leaves little excuse for their ommission, either from demonstration or from the laboratory work of the pupil." He appends a selection (by citation) of suitable quantitative experiments (p. 117).

Instruction in the classroom is discussed in Chapter V. A strong feature of this chapter is the judicious treatment of the relation of "everyday chemistry to a well balanced course." "The object of the references to everyday life will be defeated if they give occasion for long descriptions of these matters" (p. 142), and "reference to the chemistry of matters of common knowledge is suggested simply as one means of attaining the main end of the course, by making the subject memorable, attractive, and digestible," sum up the author's views. Another commendable feature is a frank though somewhat incomplete discussion of such misleading terms as "strong acids," "stable bodies," "water of crystallization," "saturation," "allotropism." We must also thank the author for referring to Pearson's Grammar of Science and the other books cited on page 153.

Chapter VI deals with some constituents of the course in chemistry for a secondary school, special attention being given to the atomic theory, valence, physico-chemical investigations, and quantitative analysis. The part devoted to the atomic theory and valence is admirable. As to physico-chemical ideas, the author rightly says (p. 168), "we cannot now teach chemistry and avoid frequent mention of electrolytic operations, and we cannot well make these explanations intelligible without some explanation of the theory." The reviewer heartily agrees with this statement, though he believes that pupils see very little in the theory and very much in the fact. The author believes that qualitative analysis can be replaced by more sensible and serviceable "exercises in identification"— a view supported by the best authorities.

Chapter VII is devoted to a detailed treatment of the laboratory and equipment. This chapter will prove very helpful to teachers who are suddenly called upon to improve their present quarters or to move into new ones. The author rightly insists on adequate equipment.

The last chapter—like the whole book—is for "the teacher, his preparation and development." Special emphasis is laid on the teacher's need of the best possible knowledge of general chemistry. He says (p. 208), "it is a knowledge of the science as a whole and not of any special section of it which will count in elementary instruction." A comprehensive list of books is appended.

The only omission of consequence is a discussion of the place of the periodic law in secondary teaching. Possibly the omission is the only discussion this topic needs!

The book is recommended to every teacher of chemistry—in college and out—as the sanest available treatment of this subject.

L. C. N.

Perhaps no better idea of the general scope of Part II. of "The Teaching of Chemistry and Physics" can be given in brief space than is furnished by the headings of the various chapters. These are: I. Whether to be a Teacher of Physics. II. Preparation for Teaching. III. The Teacher as Student, Observer, and Writer. IV. Problems of Laboratory Practice. V. School Text-Books of Physics. VI. Discovery, Verification, or Inquiry? VII. The Technique of Laboratory Management. VIII. Lectures and Recitations. IX. Physics in Primary and Grammar Schools. X. Physics in Various Kinds of Secondary Schools. XI. On the Presentation of Dynamics. XII. Plan and Equipment of Laboratory. XIII. Physics Teaching in Other Countries.

No attempt is made to present, in these chapters, anything fundamentally new or in the nature of a radical departure from present generally accepted aims and methods of teaching physics. The book offers, rather, a plain statement, usually accompanied by ample comment and suggestions, of the status of physics teaching as now provided in the best secondary schools. Considerable space is devoted in Chapters IV to X, to the Harvard Descriptive List, to the report of the National Educational Association Committee on College Entrance Requirements in Physics, and to the report of the Committee on Methods of the Eastern Association of Physics Teachers. As it is to be assumed that progressive teachers of physics are already familiar with these reports, the value of these chapters lies in the accompanying criticisms and suggestion offered by an experienced teacher, whose opportunity for observation and judgment upon the work of the secondary schools has been in some respects unusual. In all such criticism, Dr. Hall is conservative. There are few flights of fancy in his book, and much statement of fact.

Laboratory methods, the proper arrangement of periods and best grouping of students for laboratory work, the functions and special values of lecture and recitation periods, notebook keeping, and the form and character of laboratory reports, are given quite full consideration. Concerning the proper method for laboratory work, the author has this to say:

"There is very little to choose between the method of verification at its worst and the pseudo method of discovery. The former says to the pupil, 'The fact is so and so; make observations accordingly. The latter says, Make observations; from these discover the fact, which is so and so.'

We need something better than either of these methods to justify the expense and work of laboratory courses. I would keep the pupil just enough in the dark as to the probable outcome of his experiment, just enough in the attitude of discovery, to leave him unprejudiced in his observations, and then I would insist that his inferences, so far as they profess to be derived from his own seeing, must agree with the record previously made and unalterable. * * * This knowledge is not necessarily inconsistent with the fore knowledge of what the result sought should be according to the testimony of books."

A commendable feature of the chapter on "Preparation for Teaching" is the emphasis with which the prospective physics teacher is urged to pursue engineering study. A subject which, like physics, deals with transportation, construction, and the ways and means of daily industry, comfort, and pleasure, should be taken outside the class-room into real life. The teacher, who has some acquaintance with engineering terms and processes, possesses the means for adding immensely to the interest and efficiency of his teaching. Such knowledge of engineering will be a necessity to the physics teacher of a few years hence.

Only one chapter of the book is devoted to the pedagogic treatment of any specific part of physics. In this, dynamics is selected as being at once fundamental, and yet so often neglected or poorly taught. It is to be regretted that so little should be written into this chapter of a character to really clear up this too often confused and unsatisfactory part of the subject. Surely, if dynamics is to be treated at all, one has a right to expect something more helpful than a rather discouraging and negative catalogue of the difficulties which beset this particular part of physics, of error which this or that teacher who should know better, has committed, and of formulæ, most of which may be found in any ordinarily good text book in Mechanics. The equations, $f = m\ a$ and kinetic energy $= \frac{m\ v^2}{2}$ are, of course, the usual ones of the absolute system of units. To use the equations $f = \frac{m}{g}\ a$, and kinetic energy $= \frac{m\ v^2}{2g}$ for the gravitation system is to invite confusion in the mind of the pupil. Since it is the *force* which is measured in different units, and these units are g *times as large* as in the other system, logic would seem to demand the form $\frac{f}{g} = m\ a$, just as we might write 100 dimes as $\frac{100}{10}$ dollars.

But why avoid the term weight, and the equations of the engineer? While the physicist's fundamental units are mass, time and space, the engineer finds it more convenient to adapt for his, *force*, time and space. His equations are, therefore, $f = \frac{w}{g}\ a$, and $K.E. = \frac{w\ v^2}{2g}$. The engineer's term mass is therefore a name given to the fraction $\frac{w}{g}$, which he may use in the expression *force* = *mass* $\times$ *acceleration*. Such procedure may be unscientific, but it is certainly convenient and will doubtless endure. Why not recognize this, point out the origin of the practice, and then

let our use of gravitation units conform to that of the business world? One properly expects the author to do this after the position taken earlier regarding engineering study. The book would be stronger, also, had more space been given to the subject of dynamics, even had this required a curtailment of the discussion of special laboratory procedure of less general value or use, such as the preparation of tubes for the coefficient of expansion of air experiment, or the omission of rules for the use of the double-platform balance.

One is inclined, also, to take issue with Dr. Hall regarding the suggestion that a secondary school teacher should confine himself to problems on the adaptation of simple and sometimes crude apparatus to laboratory work, as being more in keeping with his attainments, instead of giving a part of his time to wider reading and investigation, thus obtaining the stimulus which may come through time thus spent, even though no actual use may be made of such material or information in the class-room.

However, as a whole, the book must prove a valuable one for the young teacher starting on his life work—whom, if we read the prefatory note, we must believe the author had prominently in mind in writing the book—as well as suggestive to the more experienced teacher. A detailed description of a very complete laboratory of a general type, suitable for secondary school work, and a brief account of the status of physics teaching in other countries, are given in the closing chapters.

J. M. Jameson.

Reports of Meetings.

UPPER PENINSULA EDUCATIONAL ASSOCIATION.

The association held its seventh annual meeting at Marquette, Mich. October 30 to November 1, 1902. One of the most helpful features of the program was the address, Friday night, by President Angell, of the University of Michigan, on "The Reflex Influences of the Teachers' Profession." He pointed out some of the dangerous tendencies that teaching stimulates in the teacher—pedantry, egotism, etc., and the more desirable traits almost unconsciously acquired.

An occasion of much interest was the dedication of the new science building of the Northern State Normal School. This is a two-story, brown stone building, 65x105 feet, used for the science work—the first floor for chemistry and physics, the second for biology. The building has been but recently completed and occupied. In President Angell's felicitous dedicatory address, he emphasized the value of the scientific training in imparting to the student the scientific method of thinking—exact induc-

tion from known facts, rather than the loose knowledge and theorizing that marked many subjects before the scientific method was in vogue.

Hon. Delos Fall, in accepting the building for the state, spoke in commendation of the work of those early educators in the Upper Peninsula, to whose ideals and efforts we now owe so much.

No meetings of a special Science Section were held during the Association Session, except one to organize, so that next year the science teachers and others interested may meet for the discussion of their own special problems. The science teachers, however, met informally to look over the new building and its equipment, and to see a demonstration of projection work with the stereopticon and microscope.

Reported by ELLIOTT R. DOWNING.

Correspondence.

EDITOR SCHOOL SCIENCE:

Aside from suggestions made in an article on the subject in the October number of SCHOOL SCIENCE, I have noticed that amoebæ are apt to occur about fresh water sponges.

They can be readily distinguished from the amoeboid cells of the sponge by their greater activity, more transparent bodies, and much greater size. Then, too, the amoeboid cells of the sponge are often filled with ingested food particles and are more nearly spherical in form than are the free amoebæ. Picking apart a bit of sponge on a slide will usually yield a number of large active forms.

Central High School, Grand Rapids, Mich. GRACE F. ELLIS.

EDITOR SCHOOL SCIENCE:

On page 195 of the October number, Professor Norton speaks of the lack of modern methods in physiography. Most of the teachers who are responsible for the conditon are fully aware of it, but do not see their way clear to change. Even in those few schools where special training for physiography has been demanded a teacher who received his training six or eight years ago might be hopelessly old fashioned and in most smaller schools physiography goes to the one with a vacant period.

Unless the teacher can take a summer course, he is at sea. Most books, either physical geographies or geologies, give general principles enough, but the teacher needs to know *exactly* what a certain spot in the neighborhood illustrates, and everything about must be known in detail to have a field excursion at all satisfactory. If one could only secure the services of an expert for about a week and tramp about the country with him, the work would be comparatively easy. Next to such help come such articles as Mr. Goodrich's (SCHOOL SCIENCE, Vol. I., p. 249). While our time is too limited to admit of the number of excursions Mr. Goodrich took and our little creek did not show all that his stream did, I followed the plan of his work quite closely, and was pleased, though not entirely satisfied with the results. I shall look eagerly for something more along that line.

Mr. Grout, in his article in the October number on "Laboratory Material for General Biology," stopped too soon. He had not reached my chief trouble, but possibly he has not contracted the foolish habit of keeping all kinds of living specimens for his classes to study. I have a decided preference for living things and am harassed every year by the fear that they do not get enough to eat. The biologies state that they will eat this, that and the other thing, but I can't get them to do so. I should be glad to learn sometime how other people feed snakes, frogs, turtles, giant water bugs, water scavenger beetles, etc., etc. Only the water bugs and whirligig beetles will touch beefsteak, books and *books* to the contrary, notwithstanding, and my snakes will not eat even small mice. I console myself with the thought that they usually hibernate, but have serious doubts as to their real happiness.

Teacher of Biology, Morrison (Ill.) High School. HELEN A. SOUTHGATE.